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HISTORY OF AIRPLANE DESIGNS IN THE USSR UP TO 1933

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24 July 1974

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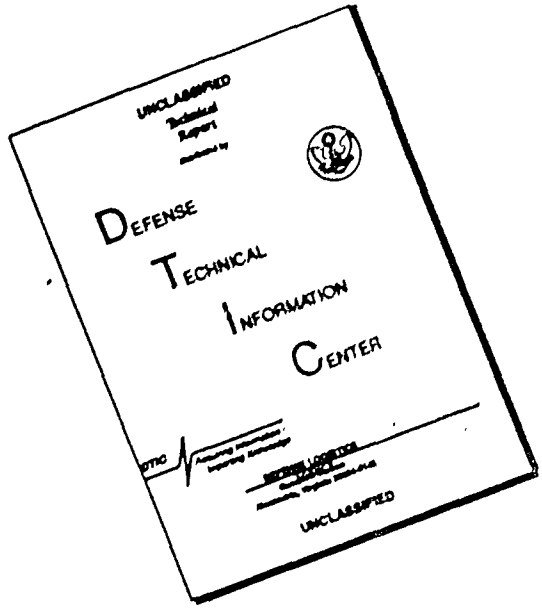

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Some of the early Russian airplanes, particularly those designed by I. I. Sikorskiy, are examined in these extracts from the book. Discussion includes materials used, engines, types of structures and joining parts, and performance data on many of Sikorskiy's earlier designs, and goes into the "Il'ya Muromets" series of airplanes in rather exhaustive detail, from the standpoint of their original design, record-setting capabilities, and combat record during World War I.

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The Work of F. I. Bylinkin, V. V. Iordan and I. I. Sikorskiy[1]

Besides A. S. Kudashev, who belongs to an older generation, the Kiev airplane designers were basically young people, primarily students. Some had parents of means, and others earned their own ways in life. The latter did not always succeed in bring their airplanes to completion. A striving arose toward combination of forces, although it was temporary. Many enthusiasts were fully satisfied with the role of participants and executors. This is how the small design collectives were put together and how, in 1910, F. I. Bylinkin, I. I. Sikorskiy, V. V. Iordan and others, students at the Kiev Polytechnic Institute, worked.

Fedor Ivanovich Bylinkin -- son of a wealthy merchant -- worked for three years on experiments in airplane building.

Igor Ivanovich Sikorskiy[2] -- son of a Kiev professor of psychiatry -- was one of the organizers of a student air navigation circle at the institute. A talented designer, having means available, he organized a production base -- a work shop in two hangars built by him at Kurenevka close to Kiev.

Vasility Vladimirovich Iordan did not have any means and brought into any business only his creative labor. Being an artistic craftsman and designer, he helped much in creation of the first collective airplanes and can be considered a full co-creator of some of them.

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[1] "Journal of Air Navigation" 1910, No. 13: 1911, No.2.
"To Sport !" 1912, No. 11
"Heavier Than Air", 1913, No. 14, pp 2-11
"Adler, B.P. Development of Russian Aviation Designs Before the Start of the First World War, Dissertation, 1946, pp 30-34,42-50,65-73,69-70

[2] Later a very well known designer, from 1918 - an emigrant

The students Gregoriy Petrovich Adler, Konstantin Karlovich Ergant, Anatoliy Anatol'yevich Serebrennikov, Mikhail Fedorovich Klimikseyev, mechanic-motorist Vladimir Sergeyevich Panasyuk and others also participated in building the airplanes of F. I. Bylinkin and I. I. Sikorskiy. The work shop of I. I. Sikorskiy also accepted orders from outside. Thus, the airplanes of A. D.Karpeka which are described below, were built in it.

The first works of F. I. Bylinkin and I I. Sikorskiy did not yield positive results. Apparently, one of the reasons for this was the fact that the designers during the first period of their activity worked separately from the collective and even outside the student circle.

The "Bylinkin-Wright" was a reproduction of the Wright Brother's bi-plane, but of somewhat smaller dimensions with a 25 hp "Anzani" engine and two Shovyertype propellers. The landing gear was with wooden wheels. The airplane was built in the autumn of 1909. In winter its power group was tested, but without success: the chain drives to the propellers broke. During one of the tests the airplane burned up due to an explosion in the carburetor.

The first helicopter of Sikorskiy (S-1) was the inventor's own design. The basic apparatus was a rectangular braced wire cage without gear; a 25 hp "Anzani" engine was instalied on the floor, towards the center of the cage was a drive to coaxial shafts which were made of steel tubes; on the shafts were two-blade rotors, the upper one with a diameter of 4.6 m and the lower with a diameter of 5.0 m. The blades were made of steel tubings with a linen covering, braced with wire to the shafts. The apparatus was built in May - July of 1909. Tests were unsuccessful: when the rotors

operated the apparatus fell over on its side and did not rise into the air.

The second helicopter of Sikorskiy (S-2) (fig. 30) had two three-bladed rotors, installed on the small four-sided cage with a pyramid, made of steel tubing and braced. The blades had a framework -- spars and ribs -- and were braced to the shafts. The engine was a 25 hp "Anzani". This apparatus, finished in the spring of 1910, was also not able to take off. Its schematic, not having a skewing mechanism and control organs, was unsuitable for flight, as was proved by B. N. Yur'yev in the same year. The apparatus was exhibited at the First Kiev Air Navigation Exposition.

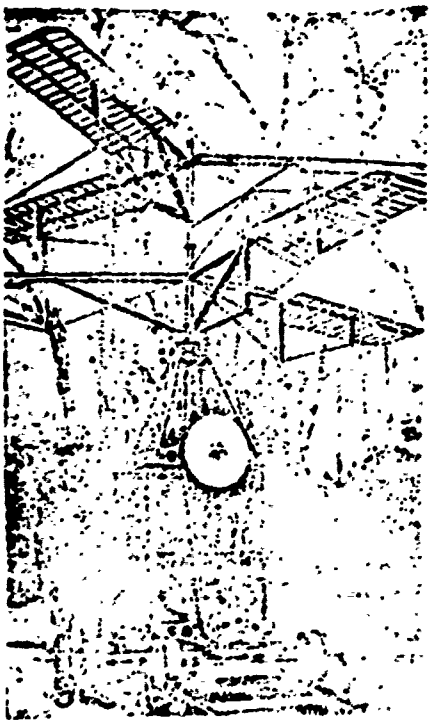

Fig. 30: The Second Helicopter of I. I. Sikorskiy

The next two airplanes of F. I. Bylinkin, V. V. Iordan and I. I. Sikorskiy were built in I. I. Sikorskiy's work shop and were fruits of their collective creativity.

The BIS No. 1 airplane (Bylinkin, Iordan and Sikorskiy) was a two-strut biplane with a truss tail. A "Anzani" engine with a power of 15 hp and a pusher propeller was installed on the rear edge of the lower wing, and the seat was installed on the front edge. Beneath the upper wing were vertical bulkheads (against slipping). Control of the height control surface was effected using a handle on the right of the pilot, and control of the aileron was effected with a handle located on the left of the pilot.

On this airplane, whose construction was completed in April 1910, its builders learned to control. The airplane could not fly; the power of the engine was insufficient. After three weeks of controlling the airplane was rebuilt into the next type BIS No. 2 with a more powerful "Anzani" engine of 25 hp.

The BIS No. 2 (fig. 31,a)[1]. The dimensions of the airplane remained the same as the previous one and only the middle cage of the wings was strengthened. The engine was installed over the leading edge of the front wing with a tractor propeller. The pilot's seat was behind the engine.

Contruction of the airplane was completed on 2 June, 1910. On another day I. I. Sikorskiy made the first flight on it, and on the 11th of June, he accomplished a successful flight along a straight line -- 200 m in length and 1.5 m in height with a duration of 12 seconds. The flight was completed in the presence of the sporting commissars of the Kiev society of air navigation. The Bis No. 2 airplane was the third Russian airplane to rise into

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1 "Air Navigation" 1910, No. 8, pp 666-668

the air in 1910.

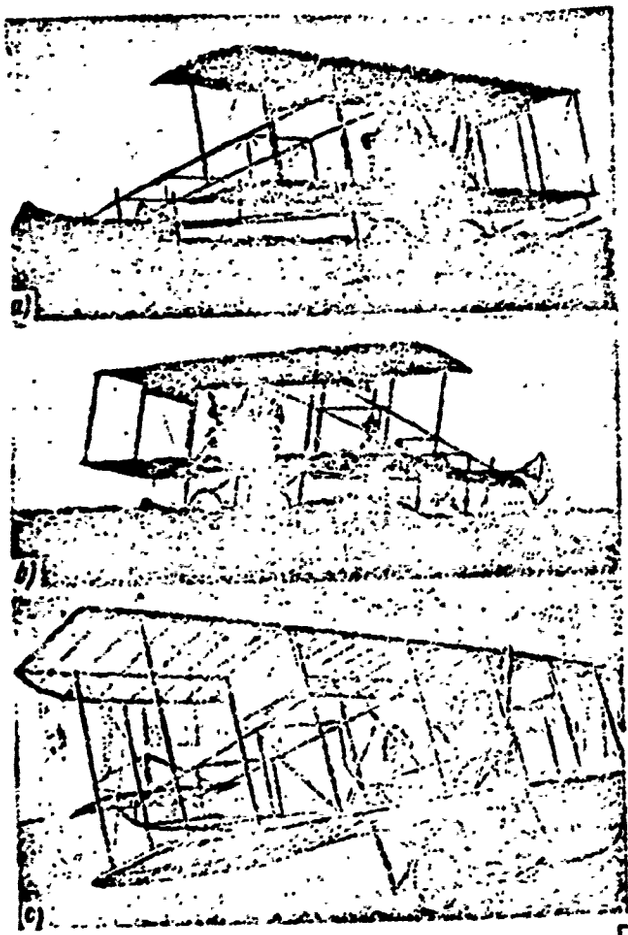

Fig. 31: First Airplanes of I. I. Sikorskiy:
a-- BIS. No. 2 Airplane b-- S-3 Airplane
c-- S-4 Airplane Rebuilt

Later, nearly fifty flights were made at a height of up to 10 m, but of low duration. On the 3rd of July 1910, a flight was accomplished with a distance of 600 m over 42 seconds. All flights were accomplished only in a straight line, there were no power reserves and with the slightest attempt to turn the airplane, lost height and speed.

The Bylinkin monoplane, finished in June - July of 1910 in one model, had two subsequent variations.

The initial variation of the airplane was with spoilers (fig. 32). The braced fuselage monoplane had a trapezoidal wing, a 25 hp "Anzani" engine, a fuselage with a triangular section about 0.4 m in height. The gear was the leading layout in 1910 with V-shaped struts and through axle on shock absorbers. The profile of the wing was formed out of arcs of circles on the top and on the bottom (of larger radius). The wing spars and fuselage longerons were of spruce, round in section. The spoilers had small surfaces (about 0.2 m^2 each) on the upper sides of the ends of the wind, deflected upward. During deflection the flow-pass of the corresponding end of the wing was deteriorated, thereby causing roll. The spoilers were an original device, used there for the first time in the world, but in this case, they were not justified. Only short hops up to 100 m in length and at insignificant height were successfully made on this airplane. Stable flight was not achieved, the power reserve was insignificant and excess drag from the spoilers reduced it to zero.

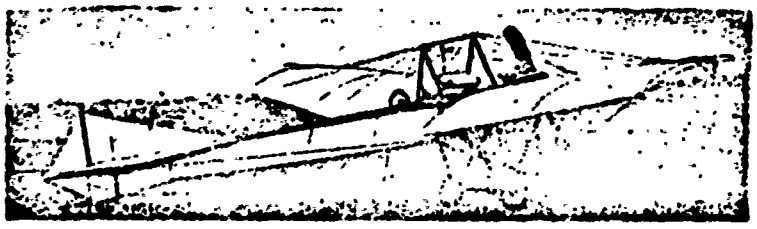

Fig. 32: Monoplane of F. I. Bylinkin With Spoilers

The changed variation was with ailerons to replace the spoilers. The ailerons, trapezoidal in plan, were fastened to the trailing edge of the wing and controlled by a lever located on the right of the pilot. An anti-

nose over beam was introduced into the gear. In this variation, due to the increase in wing area because of the ailerons, the airplane flew. The flights were short, up to 200 m in length with an altitude of up to 2 m and a duration of about 20 seconds. The airplane of F. I. Bylinkin was the fourth among the number of Russian airplanes which flew in 1910.

Up to June 1910, F. I. Bylinkin and I. I. Sikorskiy worked together. Later, their paths diverged. I. I. Sikorskiy began to develop the scheme of the BIS No. 2 airplane, F. I. Bylinkin selected a more complex schematic, which he also realized in his own biplane in the winter of 1910 - 1911. The biplane of Bylinkin, of glider design with the exception of the gear, was very close to the BIS airplane. A RAW engine of 50 hp was installed over the leading edge of the bottom wing with its nose to the rear. The propeller was a pusher one, behind the rear edge of the wing, with a shaft to the engine which passed under the seat. The wings were identical, rectangular, with a span of 8.0 m and a chord length of 2.0 m. Ailerons were present on both wings. Construction of the airplane was completed in the spring of 1911, but it did not fly: the engine worked poorly and there were difficulties in the lengthened shaft. F. I. Bylinkin soon lost interest in aviation and turned to automobiles.

The Airplanes of I. I. Sikorskiy

The S-3 (fig. 31,b) was the same type as the BIS No. 2 but was somewhat strengthened, with a 35 hp "Anzani" engine. Small wheels were added onto the front ends of the gear skids. The airplane was completed in November 1910. I. I. Sikorskiy made thirteen flights with a total duration of seven minutes on it, of which one flight lasted for 1.5 minutes. The height of the

flights was taken up to 30 m, but as before, turns were not successful. However, due to the high altitude it was possible to increase the flight range and select a site for landing outside the limits of the field from which the flight began. On 13th of December 1910, gliding from a height of 30 m, I. I. Sikorskiy made a landing on the ice of a pond. An accident occured, the engine went beneath the ice and the airplane was broken and not restored.

The S-4 (fig. 31,c). In the spring of 1910, Kiev student A. A. Gomberg, son of a local rich man , ordered from I. I. Sikorskiy an airplane with a 50 hp "Anzani" engine. According to the conditions of the order, I. I. Sikorskiy was obliged to deliver to the purchaser an airplane, having completed two circles on it. The airplane was built in one month. In layout it was a repetition of the S-3 airplane, but with an increased wing area. Ailerons on both wings were installed at a significant negative angle to provide better lateral controllability at high angles of attack during landing. During tests flights in a straight line went well, but in December of 1910, during the first flight in a circle, the engine stopped and during the forced landing, the airplane received significant damage.

After that, it was restored, during which changes were introduced into its design: the span of the upper wing was increased, the trailing edges of both wings were rounded off, the ailerons were installed in the plane of the wings, the two control levers were replaced with a control column and the front rollers were removed from the gear skids. The wing spars were made of ash, while up to that time they had been aspen. The airplane was exhibited during 1911 in that form at the Air Navigation Exposition in Khar'kov.

The S-5 (fig. 33,a) [1] was somewhat more improved by comparison with the preceding airplanes. I. I. Sikorskiy moved decisively away from the "Anzani" engines, which were very shaky and unreliable, and preferred the somewhat heavier, but more reliable "Argus" 50 hp engine to them. With installation of this engine on the airplane, the span of the upper wing was increased, a second seat and control column were installed, and struts on the upper wing cantilevers were introduced, which was a better solution than the bracing in use at that time.

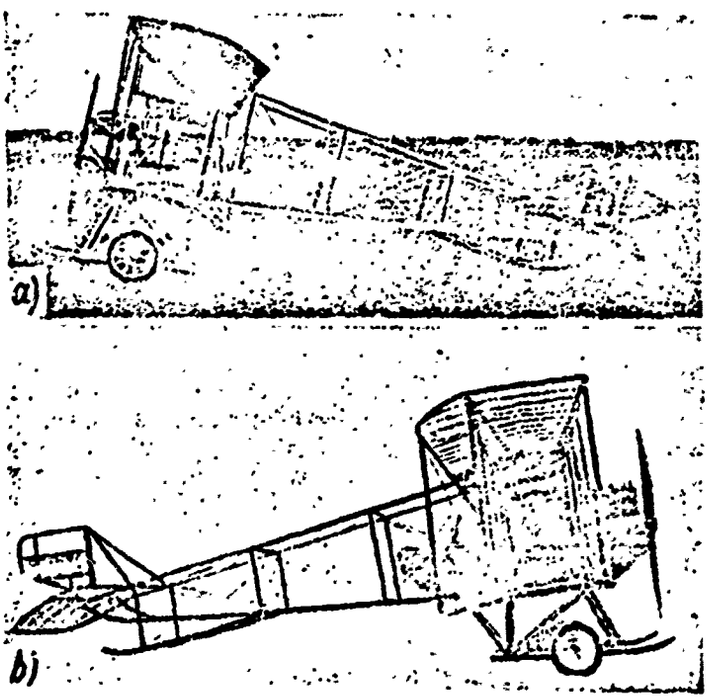

Fig. 33: Sikorskiy's Airplanes of 1911:
a-- S-5 Airplane b-- S-6 Airplane

[1] "Automobile and Air Navigation", 1911, No. 13, pg. 385
"Aero-and Automobile Life ", 1911, No. 15, 19 and 20
"Heavier Than Air ', 1911, No. 13; 1912, No. 14

Of the design features of the S-5, its gear should be noted. Beginning with the reworked -4, in the S-5 and further up to the S-7 airplane, shock absorbers were built with additional triangles, to which the axle was fastened.

The airplane was released in April of 1911. A flight along a straight line was immediately accomplished on it, for a duration of 22 seconds. On the 17th of May, I. I. Sikorskiy performed the first flight in a circle with a landing at the take-off point. The height was about 120 m. On the 14th of June, several flights with a passenger were made, and there were flights with a duration of up to half an hour with a height of up to 300 m. On the 18th of August 1911, I. I. Sikorskiy passed an examination for the title of pilot in this airplane and established four all-Russian records: a height of 500 m, a distance of 85 km, a flight duration of 52 minutes and speed relative to the earth of 125 km/h.

Construction of the S-6 (see fig. 33,b)[1] was begun in August and completed in November of 1911. Its construction preceded the first aerodynamic tests on determination of frontal resistance of parts and components of the airplane, which were conducted by I. I. Sikorskiy on a home-built circular installation.

The designers took measures to see that the high quality of Russian aviation designs won universal recognition. After the S-5 airplane, the name of I. I. Sikorskiy became well-known in Russia, and all the same, the

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[1] "Air Navigation Technology", 1912, No. 3 pp 168-172; No. 2 -- two photos of the airplane, page 112
"Heavier Than Air", 1912, No. 1, page 2
"To Sport !", 1912, No. 6, page 11
"Sebastopol Aviation Illustrated Journal", 1912, No. 1 (48-49); No. 8 (56-57).

S-5 airplane remained only in intermediate type, and an airplane was needed with higher, record-breaking indices. The S-6 airplane, in layout and dimensions almost coincided with the S-5, but differed from it with its three-place gondola (the product was located in the rear) and more careful finishing. The fuel tanks were made streamlined and drawn up directly against the upper wing, the wheel hubs were closed with aluminum discs, the covering was carefully lacquered, and the plywood gondola and struts were polished. The radiator, 2.5 m in length, was made of aluminum tubes with their ends pressed into manifolds, and was installed along the upper bands of the tail truss; it gave very low drag. The engine was a 100 hp "Argus".

On 29 December 1911, I. I. Sikorskiy established the first Russian world record for speed with two and three persons in this airplane -- 111 km/h. At the same time three other records were immediately won; the record for speed with two passengers, records for speed on biplanes in general and Russian airplanes in particular.

The S-6 A (fig. 34)[1]. In the order of further improvement of airplanes of this type, it remained only for the designer to eliminate the tail truss, replacing it with a fuselage, which was done by him. The rear end of the gondola was cut off, and the bands of the tail truss were used as fuselage longerons, attached to the gondola which remained without changes. The radiator was fastened beneath the fuselage. The covering of the fuselage was ply-

[1] "Aero-and Automobile Life", 1912, No. 8, page 13; No. 20, page 14.
"Air Navigator", 1912, No. 5, page 403
"Air Navigation Journal", 1912, No. 2 page 16
"Air Navigation Technology", 1912, No. 3, page 168-172 ; No. 6, 372
"Heavier Than Air", 1912, No. 5, page 19; No. 8,page 9

wood 4 mm thick, and that in the tail part was 3 mm thick. The tail empennage remained without changes, as in the S-6 airplane. The upper wing was increased in span, the cantilevers were supported by two struts each and the ailerons on the lower wing were eliminated. Wire braces were made in pairs with wooden slats laid between them and both wound with tape (for streamlining). The resistance of the braces was decreased by almost half due to this. The length of the upper wing was 9.67 .

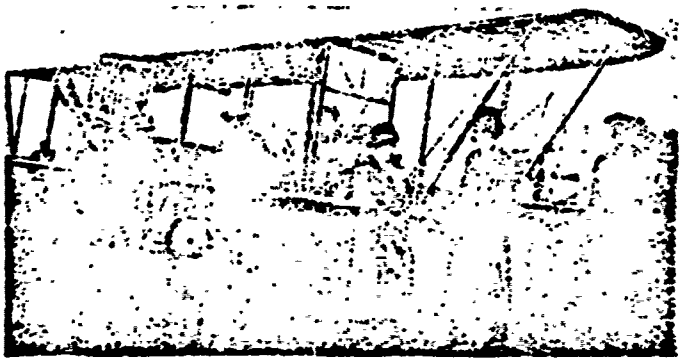

Fig. 34: S-6 A Airplane

Testing of the airplane again in March of 1912. Depending on the load and number of passengers its speed fluctuated from 111 up to 120 km/h with a load of up to 450 kg. On the 14th of March , I. I. Sikorskiy accomplished a record flight with four passengers (5 persons on board) with a speed of 106 km/h. In the April the airplane was shown at the Moscow Air Navigation Exposition, where I. I. Sikorskiy received a large gold medal for it. Then the airplane was shipped to Peterburg, where its testing continued.

In April of the same year, I. I. Sikorskiy was invited to the Russo-Baltic Railway Car Plant as chief designer in the aviation department, which in 1912 was re-based from Riga to Peterburg. Here he immediately set about building a new airplane for participation in the International Competition of the Russian Military Office, taking as the basis his S-6A airplane.

Airplanes of the Russo-Baltic Railway Car Plant (RBVZ) in 1912-1914

These included airplanes which released by the aviation department of the Russo-Baltic railway car plant in Peterburg under the direction of I.I. Sikorskiy. The technical personnel of the new department were comprised primarily of the Kiev designers K. K. Ergant, M. F. Klimikseyev, A.A. Serebrennikov,A.S. Kudashev,G.P. Adler and others who moved to Peterburg at the invitation of I. I. Sikorskiy.

Therefore, it is fully understandable that their work at the RBVZ was a continuation of their work in Kiev. Over two years up to twenty test airplanes were put out, among which were airplanes which were the largest in the world.

The S-6B airplane (fig. 47,a)[1]. The layout, dimensions and design of this airplane were insignificantly changed by comparison with the C-6A airplane. Braking hooks to shorten the runout were installed on the rear ends of the gear skids, and a semicircular fairing was made between the two seats. The gear was initially the same as in the S-6A, but in view of the prejudice accumulated at that time among military pilots against single-axle gear, they were replaced with a four-wheel gear.

A 100 hp "Argus" engine was installed on the airplane with a device for starting it from the pilot's seat. The airplane was released in July of 1912 and won first place at the Military Competition for Airplanes.

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1 "Air Navigation Technology", 1912, No. 8-9, page 534 (diagram).
"Air Navigation Journal", 1912, No. 12 Page 16
"Air Navigator", 1913, No. 4, Page 303

It showed a speed of 113.3 km/h with a load of 327 kg (before reworking the gear, the speed was 123.1 km/h with a load of 442 kg).

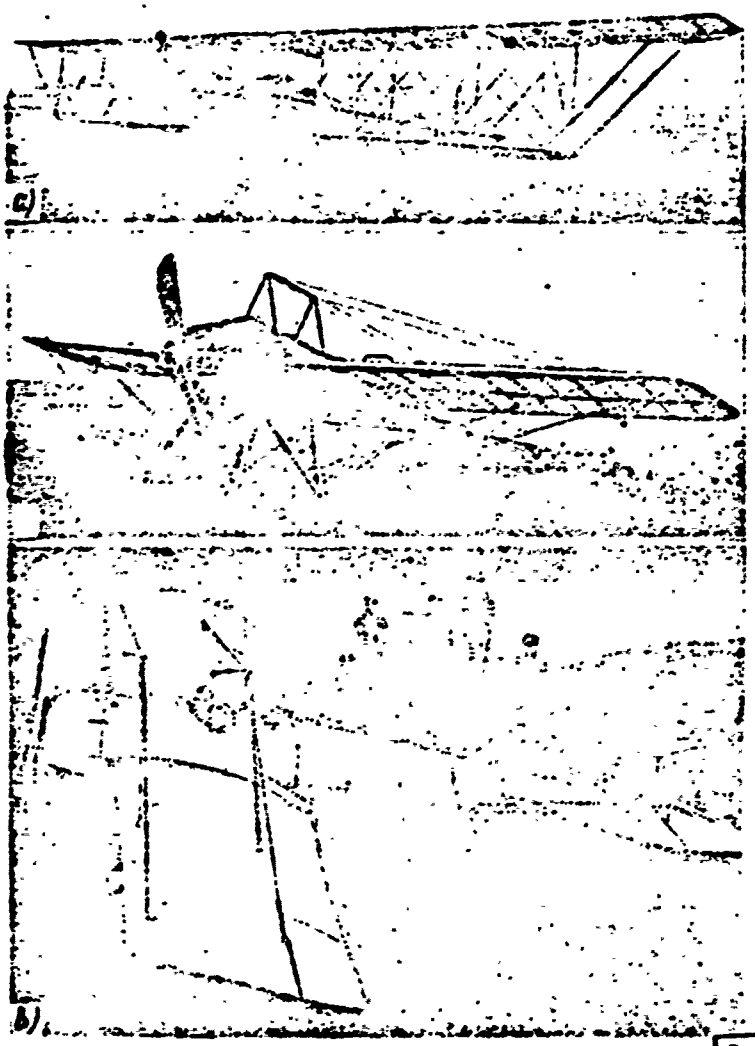

Fig. 47: Airplanes of the Russo-Baltic Railway Car Plant: a--S-6B (before reworking of the Gear) b-- S-7 (Russo-Baltic Monoplane) c--S-9 ("round")

The S-7 airplane (see fig. 47,b)[1] was built for a competition formed for this designer's group (G. P. Adler, B. V. Volyanskiy and others), it consisted of parts of the S-6A airplane and was designed for a 70 hp "Gnome" engine.

The S-7 airplane was a two-place monoplane with a gear like the S-6A, a fuselage of plywood on an ash frame, wings with ailerons, and empennage like on the S-6B, without a vertical stabilizer and having a frame type control column.

The airplane was put out in July of 1912 and participated in the competition, but due to breakage of the gear, it did not complete the competition program. Later it was sold to Bulgaria, where it was sent into the theatre of military operations[2].

The S-8 ("Malyutka" ["Pigmy"]) airplane (see fig. 50,a)[3] was a biplane trainer with a 50 hp "Gnome" engine. The pilot's and student's seats were located side by side, and behind them was the wide semi-circular fairing of the upper side of the fuselage. The pedal controls were dual and the control column was single, moving along a frame in flight. The front part of the fuselage was made of 3-2.5 mm plywood on an ash frame, assembled with wood screws and furniture glue and the tail part was linen with wire bracing.

The wing cells, of the S-6A type, have three struts with slanted braces on the outer panels of the upper wing. The lower wings lacked 0.5 m of

1 "Air Navigation Technology", 1912, No. 8-9, pp. 575-576
"Air Navigation Journal", 1912, No. 12, page 17

2 Notes of K. K. Ergant (Contral House of Aviation and Astronautics in the M. V. frunze.

3 "Aero-and Automobile Life", 1912, No. 23

reaching the fuselage, forming spaces for vision downward. The landing gear and empennage were of the S-6A type. The speed was 80 km/h. In this airplane, I. I. Sikorskiy, on September 17, 1912, performed a night flight with a duration of 1.5 hours at an altitude of 1500 m with a landing by the light of bon fires at the Komendantskiy airport in Petersburg.

The S-9 ("Krugliy" ["round"]) airplane (see fig. 47,c) is interesting in that in it a fuselage design of the monocoque type was accomplished for the first time in Russia. The layout of the airplane was that of a wire braced center wing. The fuselage had a round section and was made of plywood on a pine and ash frame without glued sections, since the tail part forming it was straight. The thickness of the plywood was from 5 mm in the front part to 3 mm in the tail. The airplane was three-place. The wings, almost rectangularly shaped in plan, were well joined with the fuselage with fairings. The braces, load-bearing and reverse, were wire pairs with slots between them and with wrapping. The lower parts of the landing gear arcs were steel, hollow-bodied, welded out of sheets, and straight -- ash with a streamlined section. The airplane was released in the spring of 1913. Regardless of its improved layout and design, it proves to be unsuccessful. Its 100 hp "Gnome" engine yielded an actual 80 hp, the monocoque came out being heavier than calculated and all dimensions of the airplane were increased somewhat. Flight weight turned out to be nearly 1000 kg. Even with a "Gnome-Monosupap" engine, the airplane did not attain the speed of 100 km/h and after test flights, work on it was stopped.

The S-10 airplane. Nearly sixteen airplanes which were similar in type and their modifications with various engines, land and sea planes were united under this name. According to layout and design, they differed little from

the S-6B airplane and were three-and four-strut biplanes. Their seaplane variations are described below.

The S-10 1913 competition airplane was especially built for the military competition with consideration for its relatively complex requirements. The S-10 was in the essence of the latter "weakened" variation of the S-6B airplane. The engine was replaced with one which was smaller in power (an 80 hp "Gnome"), and the load-bearing surfaces were increased due to the strength of the design. The span of the upper wing was increased up to 16.9 m and the outer wings were folding and could be dropped during storage. Between the lower wings and the fuselage was a space of 0.45 m for vision downward. Two seats were located side by side and the control column swung from one pilot to the other.

At the competition the S-10 airplane (fig. 48,a) gave the following indices: maximum speed 99 km/h, stall speed 67 km/h, time of climb to 500 m of 5 minutes 20 seconds, take-off run 80 m, roll-out 60 m, loading weight 444-525 kg. On 25 September 1913, the pilot G. P. Alekhnovich flew more than 500 km in this airplane without a landing, and remained in the air four hours 56 minutes and 12 seconds. This was an all-Russian record[1].

On the whole, the S-10 airplane won the highest number of points, although as a military one, it lagged behind the S-6A and S-6B airplane, possessing neither their speed nor their maneuverability. However, its load ratio of 45-48% was absolutely exclusive. During the next year, this example

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[1] "Air Navigation Technology", 1913, No. 9-10, pp 440-450
"Air Navigator", 1913, No. 12, page 871

of the S-10 was reworked for the 100 hp "Gnome'Monosupap" engine and sent to the front. With this, the wing span was decreased by one arch and became 13.68 m for the upper wing, and the dimensional area of the wings became 35.5 m^2 instead of 46 m^2.

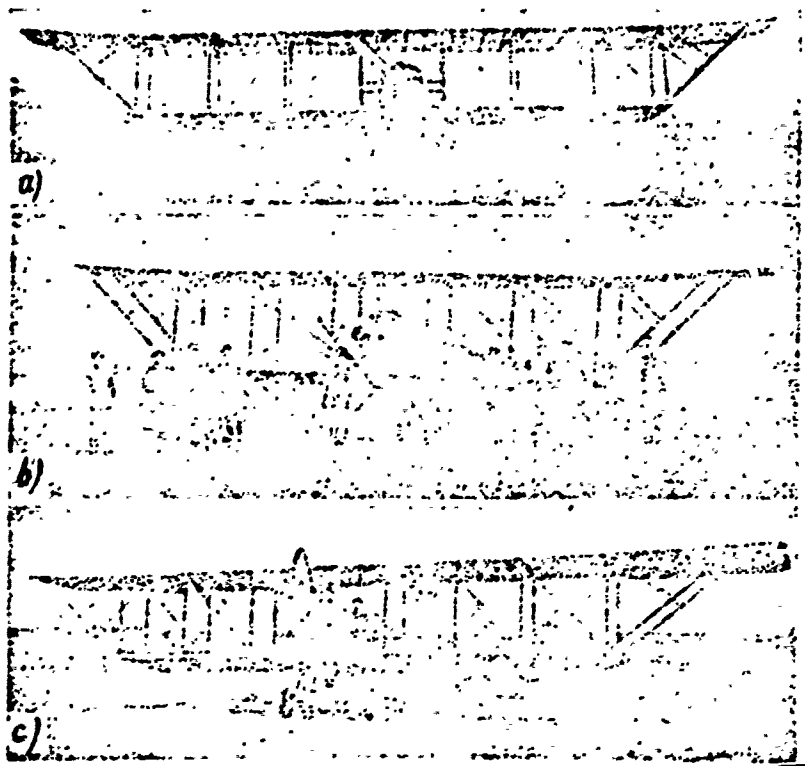

Fig. 48: S-10 Airplanes:
a-- S-10 Competition Airplane b-- S-10A Airplane
c-- S-10 Airplane with "Argus" 100 hp Engine

The S-10A 1913 competition airplane (see fig. 48,b)[1] differed from previous ones in that the seating was tandem (with the pilot in back) and the wing span was decreased by one arch on each side. Due to the extreme simplicity of the connecting components of the wing spars (flat plates) it

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1 "Aero-and Automobile Life", 1913, No. 18, Page 13
"Air Navigation Technology", 1913, No. 9-10, pp. 440-450

was always possible to install these arches and their strut again. The outer panels were fastened on hinges and could be lowered for convenience in storage. The engine was a 125 hp "Anzani" (actually 100 hp). The speed and ceiling of the airplane in this variation were significantly higher than in the previous airplane, but nevertheless its indices did not give basis for expecting success at the competition. Therefore, its testing was not brought to completion, although pilot G. P. Alekhnovich established an all-Russian altitude record -- 3420 m on this airplane, and from this altitude glided from Krasnoye Selo to the Korpusniy airport. Later, the "Anzani" engine was replaced by a "Gnome-Monosupap" and in August of 1914, the airplane was installed on floats.

The S-10 airplane with the 100 hp "Argus" engine (see fig. 48,c)[1] was released in 1913 in two non-identical models with three-and with four- strut box wings, with which the flight weight reached 1150 kg, including a load weight of 500 kg (a load ratio of up to 44%).

One S-10 airplane was with a 100 hp "Gnome-Monosupap" engine and a two-strut box wing.

The S-11 "half-round" airplane (fig. 49,a)[2], a braced midwing airplane, built with consideration for the requirements of the 1913 competition, was a development of the "round" airplane in the direction of lightning, decreasing dimensions and replacing the monocoque with a braced fuselage. The engine was a "Gnome-Monosupap" with a 100 hp. In the wings there were originally ailerons with rigid control, into whose system went steel tubes, working

[1] TsGVIA [Central State Archives of Military History], f. 813, d. 14112,l.155

[2] "Aero-and Automobile Life", 1913, No. 18 p 13

on torsion and passing through the wing from the root to the aileron. After the competition, the ailerons were replaced with warping, since they were small. The linen was covered with airplane lacquer, and along it was oil lacquer. The gear axle was made of steel tubing with ash plug beneath the struts. The airplane's center of gravity was approximately one third the wing chord.

The airplane was designed for the purpose of reconnaissance. The seating was side by side and control was only from the left seat. At the competition the airplane received second prize, having showed the data: maximum speed of 102.3 km/h, stall speed of 71.6 km/h, time of climb to 500 m of 6 minutes, 15 seconds, take-off roll of 77 m and rollout of 55 m.

The S-12 airplane (see fig. 49,b)[1] was a lightened variation of the S-11 airplane, built upon the suggestion of the pilot, G.V. Yankovskiy as a trainer, of smaller dimensions with a "Gnome" 80 hp engine and a flying weight of 681 kg. This was the first airplane of Russian design in which in September of 1913, G. V. Yankovskiy performed the loop on it he established an all-Russian altitude record -- 3680 m. The S-12 airplane proves to be successful, and was built in a small series (10-12 copies) with a "Rhone " 80 hp engine; it served in units of Soviet aviation during the civil war right up to 1922.

The "Russian Champion" Airplane[2]

The "Russian Champion" was the first four-engined airplane in the

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1 TsGVIA[Central State Military Historical Archives]] f. 2008, op 1, d. 512. 11. 226, 259.

2 "Heavier Than Air", 1912, No. 14

world, the first-born of heavy aviation. The history of its creation is such. After refusal of the military department to accept the S-6B airplane into the inventory, the plant management allowed I. I. Sikorskiy to build on the order of an experiment a "large airplane for strategic reconnaissance". The product was developed and a number of investigations were conducted in aerodynamic laboratories, during which installation of both two and four engines on the airplane was provided beforehand.

The airplane, originally called the "Grand-Baltic" (sometimes called the "Grand" and "Large Baltic"), was built at the RBVZ in the winter of 1912-1913 in a situation where even aviation specialists did not believe in the possibility of flight of a large airplane with several engines.

In March of 1913, the airplane was shipped to the Komendantskiy Airport. Initially, two "Argus" 100 hp engines were installed on it (fig. 50,a,d Table 10, page 212). On 2 (15) March, the "Grand" was first tested by I. I. Sikorskiy. The flight was conducted successfully, although it was clear that the 200 hp output of the engines was insufficient. The ceiling of the "Grand" did not exceed 100 m. Immediately after the first tests, two more "Argus" engines were installed on it in tandem with the first one (see fig. 50,c) since the designers feared the appearance of strong torsional moments in a case of failure of the engines on one side. For this reason, two directional rotors were made with a convexo-concave profile (like in the wing) with the convex side outward, thereby providing a restoring moment on the rotor in the flow of the propeller. The rotors had horn compensation, and there were no vertical stabilizers. The first flights of the four-engine airplane, beginning on 10 March 1913, showed that these fears were unfounded. Upon stoppage of any of the engines, the airplane normally performed turns in

the direction of the working engines. After this, I. I. Sikorskiy bravely set all four engines in a line with tractor propellers, adding with this two more directional rotors (fig. 51). This was still more advantageous because it increased the overall thrust of the air propellers, since with the rear propellers in tandem, as is known, the thrust is always less than that of the front ones.

The first flight of the airplane with four engines installed in a row was conducted on 23 July 1913. The airplane responded to the rotors remarkably when two engines on one side were shut down. The vitality of this layout, the basis for all multiengine airplanes, was proved. The "Grand" airplane was at this time remained "the Russian champion".

Over a year, I. I. Sikorskiy made scores of flights on this airplane, including a number of flights over the vicinity of Petersburg with duration of up to one hour and 54 minutes with seven passengers on board, establishing with this a world record (on 2 August 1913). There were no accidents and success was total. I I. Sikorskiy was awarded the rank of engineer.

The dimensions and weight of the "Russian Champion" exceeded by approximately double all those which were then in airplane building technology: the span of the upper wing was 27.0 m, the area of the upper wing was 70 m^2, that of the lower was 50 m^2 and flying weight was nearly 4200 kg (see Table 10). In layout, it was sort of an enlarged S-6B airplane, but due to the absence of staggering of the engines and a long fuselage, the center of gravity of the airplane was located behind the wing cell, and its empennage was made to be load-bearing and significant in dimensions. This layout could be called the biplane-monoplane-tandem. For that time it was the best

in that airplane.

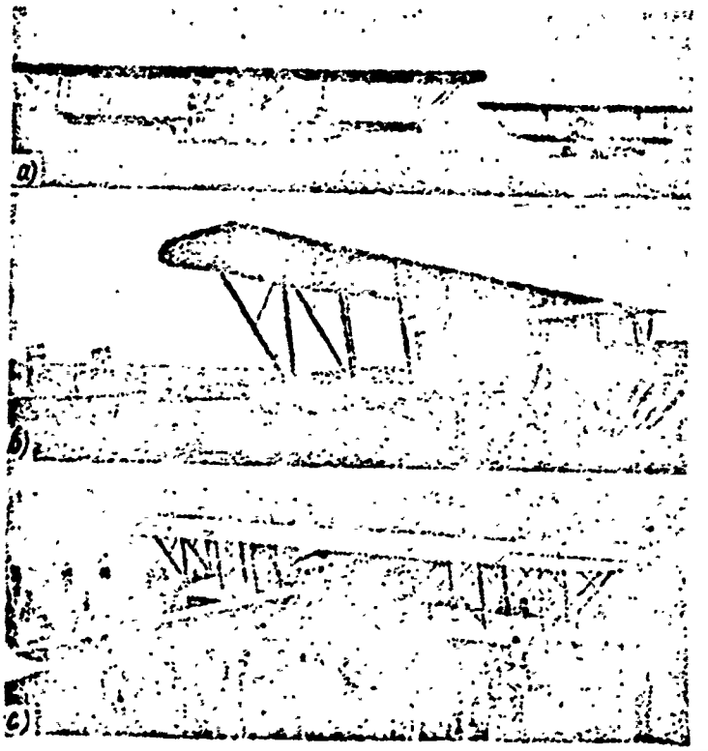


Fig. 50: The "Grand-Baltic" ("Large Baltic") Airplane:
a--"Grand" and "Pigmy"
b--"Grand-Baltic" with two engines
c--"Grand-Baltic" with tandem installation of four engines

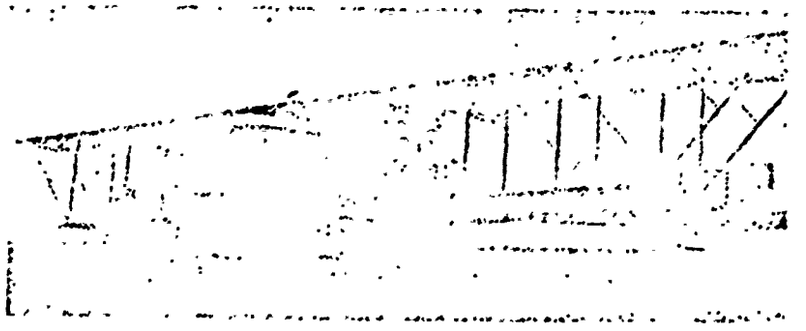
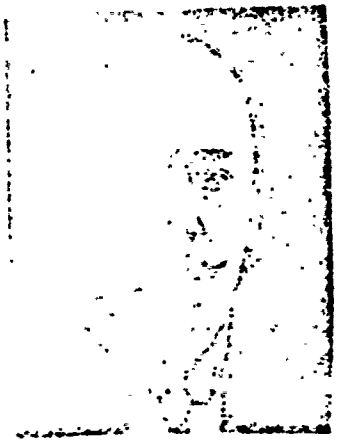


Fig. 51: The Russian Champion Airplane

The wing cell was four-strut, and the wings were two-spar with a thin profile with a rise of 1/21. The spars were box type, their walls out of 5 mm plywood and their floors out of pine, 18-20 mm in thickness. The height of the spars was 90 mm, and their width was 50 mm; they were assembled with furniture glue and brass screws. The ribs had walls of 8 mm plywood and floors out of pine laths 20x8 mm in section with a groove 3 mm deep for fastening the plywood walls in them with glue and nails, driven through the floor into the edge of the plywood wall. The covering of the linen was enamelite (airplane dope). The bracing was 3-3.5 mm piano wire.

The fuselage consisted of a four-sided box construction, made of Kostovich arborite. The fuselage longerons were ash, 40x40 mm in section in the middle part, the thickness of the arborite was 4 mm, and braces and laths were pine. The width of the fuselage in the front part was 1.4 m with a gradual decrease to 0.6 m in the tail. The height at the nose and middle parts of 0.9 m went down almost to zero at the tail. The fuselage was very thin and therefore had to be strengthened with tie rods having tension members above and below out of 3.5 mm piano wire. The nose part of the fuselage formed an open balcony, behind which went the enclosed glass cabin 5.75 m in length and 1.85 m in height, projecting over the fuselage. In the cabin, in front were two seats for the pilots, and behind them was a glass bulkhead with a door into the passenger compartment of the cabin, closed with an arborite fairing. In the cabin there were several woven seats and a table; visibility from it was not exceptional. This was the first large enclosed cabin on an airplane in the world.



Igor Ivanovich Sikorskiy

The gear of the "champion" was relatively cumbersome. Two four-wheeled carriages (with two pairs of wheels on each) were fastened between the skids on bungee cord shock absorbers and a system of guy wires. The gear worked without failure. Besides the carriages, the load-bearing braces of the wing cell, inserted in an addition to the crosses of the braking between the wings, were fastened to the gear skid. Control of the airplane was with two columns and pedals and it was transmitted with cables. The fuel tanks were made of 0.6 mm brass. Tube radiators were installed along the sides of the inboard engines.

The "Russian Champion" did not exist for long. On 11 September 1913, at the 3rd Competition for Military Airplanes an engine from the "Miller-II" airplane, flying above it, tore loose and fell on its left wing cell, seriously damaging it. After this, the airplane was not restored, because its wood had already had time to get wet and doubts arose as to its strength.

The role of the "Russian Champion" airplane in the history of aviation is great. It was the prototype for all future heavy airplanes with engines installed in a row on the wing, regardless of their layout. The airplane was

successful and served as an example for the great and fully earned national pride. A direct continuation of it was the "Il'ya Muromets" airplane, construction of the first copy of which was finished in October of 1913 (see page 191).

Seaplanes of I. I. Sikorskiy 119/

The S-5a airplane, a two-float seaplane (fig. 73,a, see Table 11) was built at the end of 1912 on the order of the naval department for a "Gnome" 60 hp engine. According to type and layout the machine was similar to the S-6 A airplane, but with a three-strut wing cell which was decreased by one section, with two stepless floats and a third float -- a cylinder beneath the tail. The width of the fuselage was decreased slightly toward the tail, but its height was reduced almost to zero. However, due to the plywood construction, the fuselage generally possessed sufficient rigidity, although it was less than a fuselage of normal dimensions. The airplane was tested at the Grebniy Port in Petersburg. G. P. Alekhnovich flew in it. The engine power proved to be insufficient, the airplane was not accepted by the naval department and remained at the factory as a trainer[1].

The S-5a single float seaplane (see fig. 73,d)[2]. This airplane, about which very little information has been retained, was a second variation of the S-5a airplane on a single-float gear with outrigger floats beneath the wings and a tail cylinder. The main float had the same outline as the two

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1 "Air Navigation Technology", 1912, No. 10 page 574
"Heavier Than Air", 1912, No. 14

2 "Aero-and Automobile Life", 1913, No. 10 page 15
"Air Navigator", 1913, No. 9

outriggers- but was double width. The engine was a 80 hp "Gnome". The airplane flew better than the "Curtis" or "Farman-XVI", was accepted by the naval office as a scout plane and was sent to Rivo in September 1914.

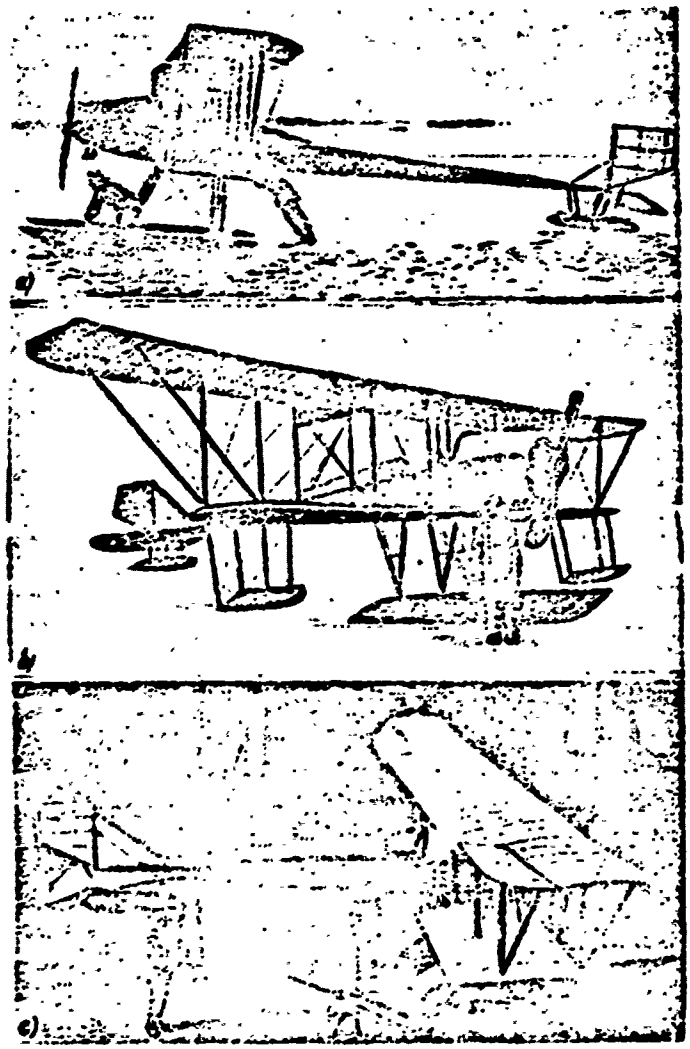

Fig. 73: Float Airplanes of I. I. Sikorskiy:
a--S-5a Two-Float airplane b--S-5a Single Float Airplane
c--S-10 "Hydro" airplane

The S-10 "Hydro" airplane. Seven seaplanes, accepted by the naval office and making up the inventory of naval aviation on the Baltic Sea in 1913-1915 were combined under this name. They participated in military actions in the beginning of WW I. They include: the S-10 -- a seaplane with a "Gnome-Monosupap' 100 hp engine and series of five models with the

"Argus" 100 hp engine, built in the summer of 1913 (see fig. 73,c).[1]

The plane looked like an S-5a two-float, differing by the seats shifted aft and more bulbous fuselage belly. Additional struts ran from the motors to the floats, tube radiators were placed along the fuselage sides, and a vertical stabilizer was introduced. In outline, the floats were copies of those on the S-5a, but were larger, a water rudder, among the first in the world, was installed abaft the tail cylinder on the rudder post. This series also includes a sixth S-10 copy with a 115 hp "Argus" engine, converted from a landplane.

Navy fliers did not like the S-10 airplane much because of their openess and lack of strength and especially feared their very thin and flexing tails. However they did not break apart in the air and one case was even noted when the pilot I.I.Kul'nev, flying this airplane on 15 December 1913 in Libav performed flight in an inverted position, floats upward, at an altitude of 300-400 m and came out of it normally[2].

Airplanes of the Russo-Baltic Railway Car Plant in 1914-1917 159/

These include five airplanes and their modifications, built at the IBVZ simultaneously with the "Muromets".

The S-XVI (S-16) airplane (fig. 92,a)[3]. This was a single-strut two-place biplane with side-by-side seating, 80 hp "Gnome" engine, a relatively large wing area, and a farman type gear. On one model with a 60 hp "Kalep" the upper wing was increased by 2 m^2. With this, the ailerons on the lower wing were eliminated, and the ones on the upper

[1] TsGVIA f.843, d.14112, l. 155
[2] "Aero", 1914, No. 1, page 21; "Air Navigation Technology", 1914, No.2-3
[3] TsGVIA, F.369, op.8, d.72, ll. 13,14,18-22,25; d.54, ll. 4-6, f.493,op.4, d.414, ll.30-4-305. f.2003, op.2, d.623, ll. 38,41,121,125; op.3, d.628, l. 169; f.2008, op.1, d.47, l.34
I.M.Kotskin, notebook of 1917, Scientific and Memorial Musuem of N. Ye Zhukovskiy

were greatly enlarged. Its armament consisted of a synchronized machine gun and some times another movable machine gun, directed backward was also installed.

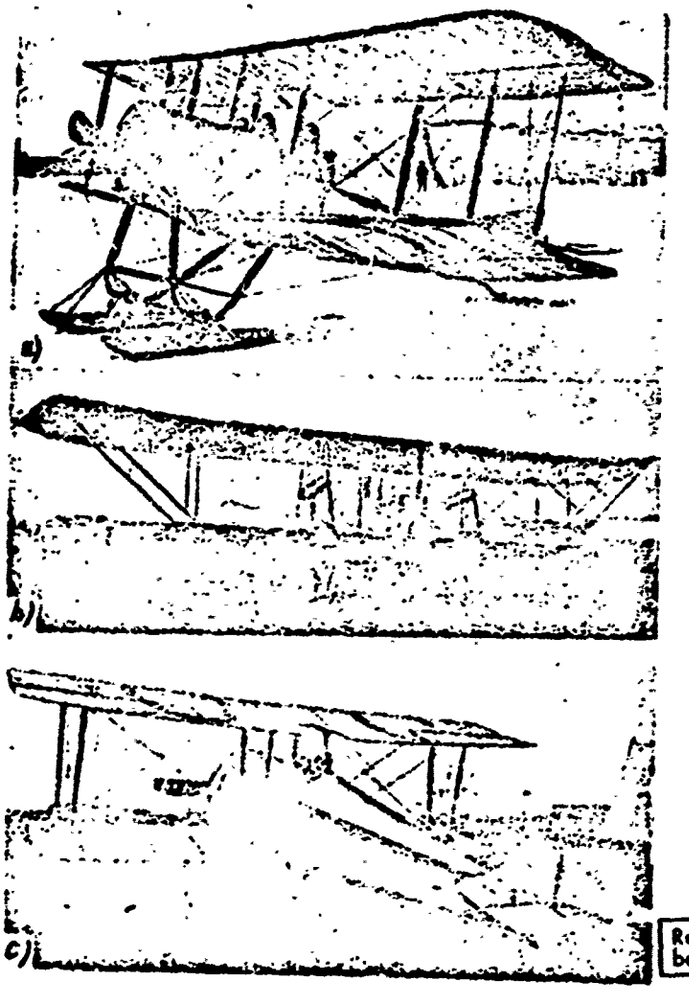

Fig. 92: Airplanes of the Russo-Baltic Railway Car Plant:
a--S-XVI Airplane b--S-SIX Airplane c--S-XX Airplane

The airplane was created as an escort fighter to protect airborne "Muromets" , and for covering their base airfields. It was put out at the end of 1915. In all, eighteen airplanes were built in January-March of 1916 and several more were built in 1917. The S-XVI airplanes were used primarily later, already in the Civil War and existed up to 1923.

There was a float version, but it did not justify itself.

The S-XVII (S-17) airplane[1] was a two-place two-strut reconnaissance biplane with spaces between the lower wings and fuselage (for visibility) and the overall appearance was similar to the S-10A. The engine was a "Sunbeam " of 150 hp. Two models were built at the end of 1915 and during the middle of 1916 they were sent to the Front. This airplane, like the twin engine S-18 following it, were then called "fighters".

The S-XVIII (S-18) airplane (fig. 93)[2] was a two-place four-strut biplane with two "Sunbeam" engines of 150 hp each installed in the lower wing as pushers.

The gunner's cockpit was in front. The fuselage was covered with plywood. There was clearly no room for a second gunner firing backward in this layout. The purpose of the airplane according to the project was "to carry to the service a fighter .....to deliver swift blows to the enemy who is flying on our territory....." . Due to the low quality of the "Sunbeam" engines, the airplane cannot even lift off the ground with a full load. Four "Gnome" 80 hp engines were installed in two tandems. In general, the testing dragged on, and the airplane arrived at the front only in May of 1917.

The S-XIX (S-19), "twin-tail") airplane (see fig. 29,b)[3] was a twin fuselage biplane with tandem installation of two "Sunbeam" engines of 100 hp each on the center part of the lower wing with a frontal radiator which was common for both engines. The fuselages were four-sided, plywood, with

1 TsGVIA, f. 2003, op. 2, d.623, 11. 89, 289, d. 624, 1. 179
K.K. Ergant, notes, Central House of Aviation Imeny M.V. Fr

2 TsGVIA f. 369, op.8 d. 54, 11.17-18; d.72, 11.13,14,25,34;
f.493,op.12, d,10, 11.15 (drawing) 36;
f.2008, op.1, d.295, 1.57; d.502, 1.110; d.512,1.100.

3 TsGVIA f.2008, op 1, d.512, 1.100

a tight cabin in the nose part of each one. The horizontal stabilizer laid on the fuselages, and the two elevators were separated by a large rotor with horn compensation. There was no armament. The purpose of the airplane was unclear and its flight qualities were determined. The airplane was built on the order of the War Office, which apparently wanted to reproduce something from the German twin-tail airplanes.

The S-XX (S-20) airplane (see fig. 92,c)[1] was a single place fighter first with a "Gnome-Monosupap" 100 hp, and then with a " Rhone " 120 hp engine. The upper wing, carrying the ailerons, exceeded the lower ones somewhat in chord and span. The airplane was built in September of 1916 in five copies. This was a very good airplane and in speed it exceeded all "Neuports", lagging somewhat behind only the "Vickers". The S-XX airplane, in its design and data was on the level of the very leading equipment of 1916-1917. Unfortunately, it was not built in series and remained almost unknown. Its float variation was not finished.

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[1] TsGVIA f.2003, d.623, 11.88, 289; d.624, 1.179,f.2008, d.492, 1.32; d. 630, 1.54

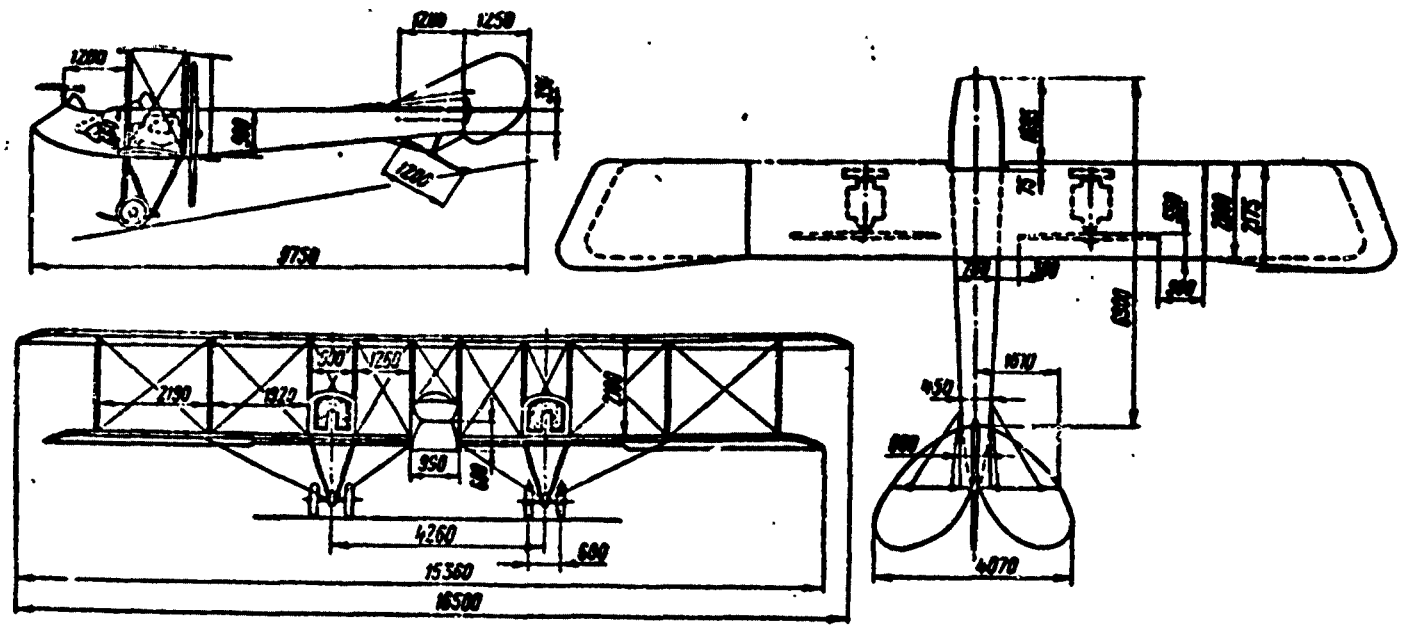

Fig. 93: Diagram of the S-XVII Airplane

"Il'ya Muromets" Airplanes

The layout and design of the "Il'ya Muromets" airplane. The large four-engine airplane of the Russo-Baltic Railway Car Plant released following after the "Russian Champion" was named the "Il'ya Muromets"[1] and this name became the collective name for a whole class of heavy airplanes, built by this plant during the years 1914-1918 (Table 10).

The "Il'ya Muromets" airplane was a direct development of the "Russian Champion" in which only the overall layout of the airplane and its wing cell with installation on the lower wing of four engines in a row remained essentially unchanged. The fuselage was principally new: for the first time in world technology, it was made as a solid whole without projection of the cabin, with a four-sided section, height greater than that of a man and without tie rods strengthening. Its front part was occupied by the cabin. The Ilya Muromets" was the prototype for all further military and civilian airplanes with a fuselage which included the cabin in the streamline body.

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1 TsGVIA f.369,op.8, d.72, 11.1-4, 13-14,29-37; op.16, d.489, 11.17-56; f.463, ( ), d.4881, 11.42,223-228 (Technical conditions for procurement of IM [Il'ya Muromets] airplanes); f.493, op.4,d.424, 11.63,66,80,144; d.441,11.217-218; d.160,11.168-169; op.7, d.92,11.1-10; op.11, d.10, 11.186,202,235,255-256; d.55, 11.60-68,73-75; d.2126, 11.9,22-24; 1.3454, 1.45.
TSGASA f.29,op.13, d.427 ; K.N.Finne, the Russian Air Knights of I.I. Sikorskiy,Belgrade, 1930; G.P. Adler, the development of russian aviation design up to the First World War, dissertation 1946, pp 177-184; V.F.Naydenov, airplanes, Pgd, 1915, p.297; "Air Navigation Technology", 1916, No.4-5, pp 105-107; "To Sport !", 1914, No.5 p.17: "Aero-and Automobile Life', 1914, No. 1,4,5,8 ; I.M. Kostkin, notebooks stored in the scientific-memorial musuem of N. Ye. Zhukovskiy

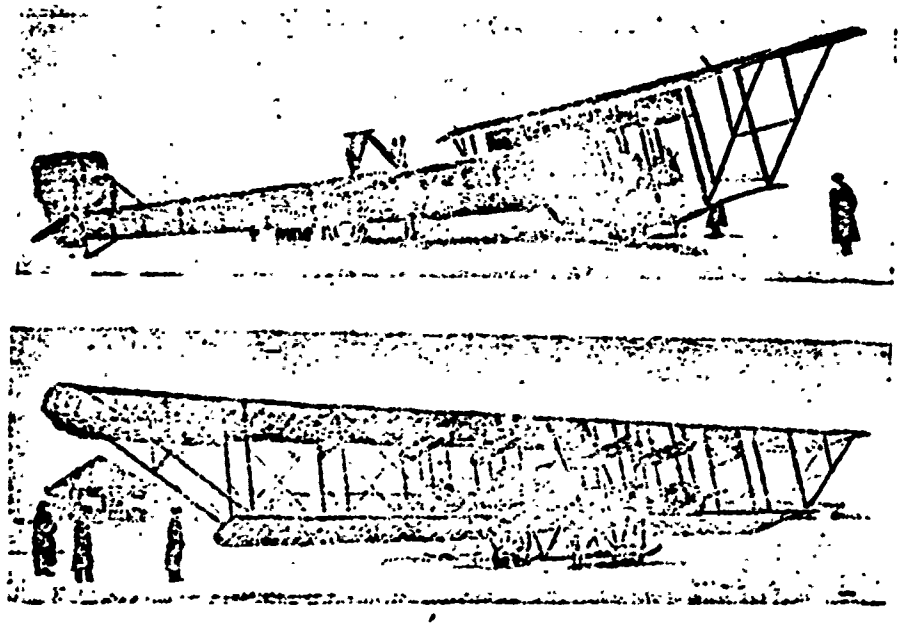

Fig. 115,116: First "Il'ya Muromets" Airplane (Plant 107) With a Middle Wing and "Equipment-Machine-Gun Platform" in Front of the Fuselage

A number of improvements in the design of the airplane allowed the achievement of significantly better results with the same four "Argus" 100 hp engines as in the "Russian Champion": the load weight and ceiling of the airplane was twice as high. The wing area of the first "Muromets" (182 m^2) exceeded the wing area of the "Champion" by 1-1/2 times, but its empty weight was only a little higher. The cabin length was 8.5 m, its width was 1.6 m and its height was up to 2 m.

It is interesting that the designers did not immediately move to the finalized layout for the airplane. The initial airplane had one additional, middle, wing with cabanes for fastening its bracing between the wing cell and empennage, and additional skids ("middle undercarriage") were made beneath the fuselage (figs. 115 and 116). At first even a whole biplane cell was installed (upon the suggestion of K. K. Ergant) and the first

flights were made in this form. However, the additional wings did not justify themselves, the load capacity was not increased due to this, and they were removed.

A platform with handrails remained from the removed middle wings, and it was possible to stand on it during flight (fig. 117).

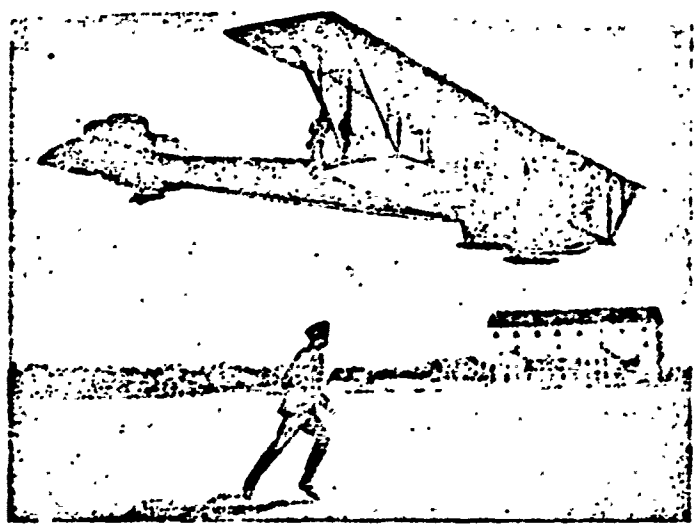

Fig. 117: "Il'Ya Muromets" Airplane (1st Copy) on Skis

There was initially still another feature in the configuration of the airplane. Considering the military purpose of the "Muromets" and proposing to use for its armament a 37 mm cannon and two machine guns, the designers installed on the middle skids of the undercarriage a "armament and machine gun platform" locating it in front of the fuselage nose and a meter below it, almost at the ground itself when at rest (see fig. 116). The gunner had to crawl onto to this platform from the cabin during flight. The platform was guarded with handrails. Later (after the series) it was eliminated.

The layout of all "Muromets" was in general, identical (fig. 118) -- a six-strut biplane with a very large span and length (up to 14 on the upper wing). The four inboard struts were grouped together in pairs and the engines, standing completely in the open, without fairings, were installed between the pairs. Access was provided to all engines in flight, for which a plywood walkway with wire handrails ran along the lower wing. There were many examples when this saved the airplane from the forced landing. On some airplanes, the four engines were installed in two tandems, and in some cases, the training "Muromets" had a total of two engines. The design of all "Muromets" was also almost identical for all types and series. Its description is given here for the first time.

The wings had double spars. The span of the upper one was about 24 to 34.5 m, and that of the lower one was 17-27 m respectively. Length of the chord was from 2.3 to 4.2 m. The total surface of the wings, depending on their dimensions, was from 120 to 220 m^2. The spars were placed at a mean of 12 and 60% of the chord length. The thickness of the wing profile amounted to from 6% of the chord in the more narrow wings and to 3.5% of the chord in the wider ones. The wing profile was constructed primitively (see fig.150). Their upper and lower contours were parallel from the leading edge to the aft spar and described an arc of a circle. From the aft spar the lower contour of the profile went approximately along a straight line to the trailing edge. The leading edge of the profile was described with a semicircle. The arch of the profile was 1-22 - 1-24.

The spars were of box construction. Their height was 100 m (sometimes 90 mm), their width was 50 mm, and the thickness of the plywood walls was 5 mm. The thickness of the caps changed from 20 mm in the wing center section to

14 mm at the wing tips. The material of the cap was initially imported Oregon pine and spruce, and later common pine. Shelves of hickory wood were built into the spars of the lower wing beneath the engines. The spars were assembled with furniture glue and brass screws. Sometimes a third spar was added to the two, behind the rear one, to which the ailerons were fastened. The bracing crosses were identical, located on a single level and made out of 3 mm piano wire with tighteners. The wing ribs were simple and strengthened, with thickened caps and walls, or sometimes with double walls out of 5 mm plywood, with very large elongated holes for weight reduction, and the caps were made out of pine laths, 6x20 mm with a slot 2-3 mm in depth, into which the wall rib went. Assembly of the ribs was done with furniture glue and nails. The rib spacing amounted to 0.3 m throughout. As a whole, the design of the wings was light.

The sections of the wing cell struts were teardrop-shaped, 120x40 mm, with a decrease toward the ends to 90x30 mm. On later types of the "Muromets" these dimensions were larger. The struts were made out of pine, glued up out of two halves and were hollow. The thickness of the strut material after milling was 9 mm in the middle struts (at the engines) and 8 and 7 mm in the remaining ones. The end angle braces of the upper wing were of the same section.

Wing cell braces were made out of piano wire (3.5-3 mm) and almost all were paired -- out of two wires with a lath 20 mm wide inserted between them and wrapped with tape on glue. The tighteners in all braces were installed on the lower ends of them. An adjacent pair of tighteners was fastened to an intermediate eye, which in turn was fastened by a bolt to a cut fitting in the strut base. Secondary braces were single, but the more heavily loaded

ones were also made triple.

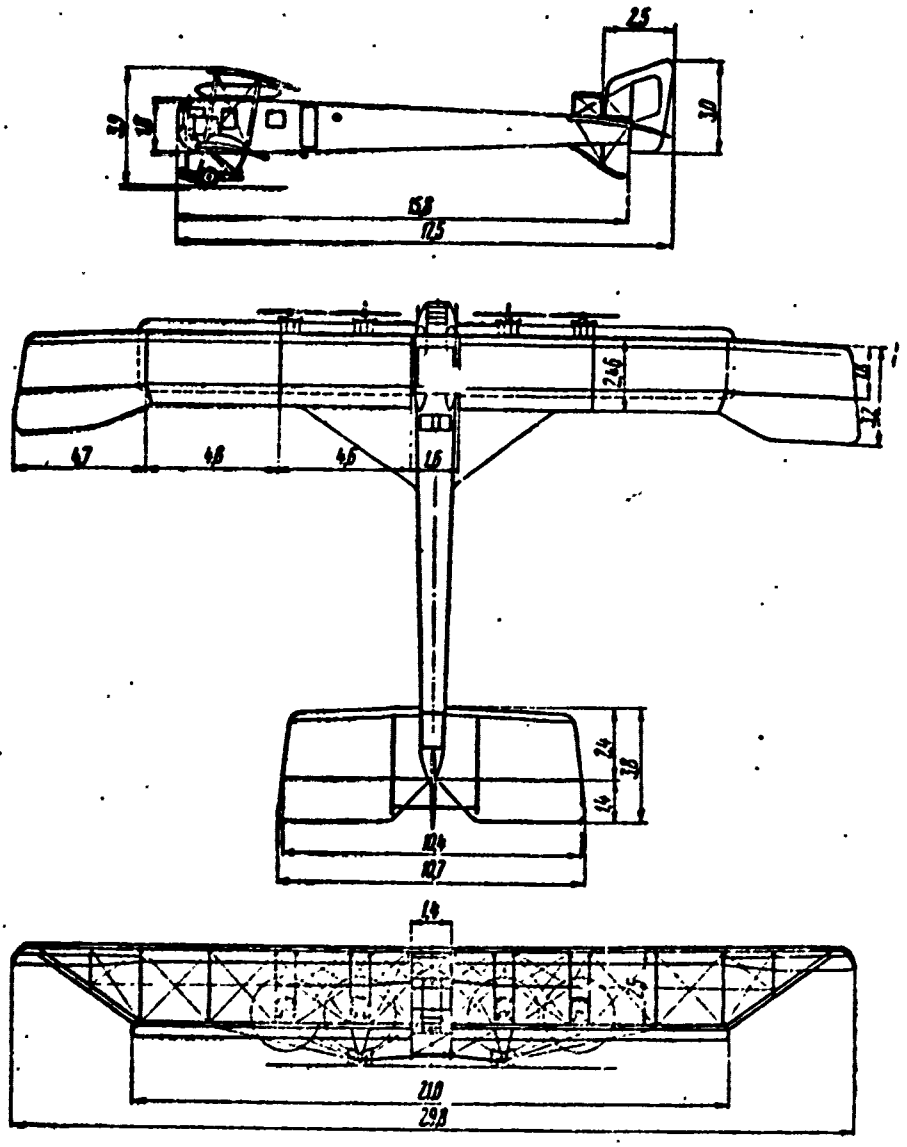

Fig. 118: Layout of the "Il'ya Muromets" Type C Airplane, 1915

The wings were made to come apart along the span. The upper one usually consisted of seven parts: a center section, two intermediate parts on each half-span and two end panels; the lower one consisted of four parts Assembly components were box-type, welded and made of soft steel (σ_b = 40 kg/mm^2). As in all other parts in the airplane, they were a very simple and expedient design. Many components consisted of the simplest flat

plates. Assembly of the units with wooden parts was done on bolts with inch thread. The larger bolts were conic (see fig. 151) with hexagonal heads, beneath which the bolt diameter was 12-14 mm, and at the end it was 8 mm.

The design of the fuselage was braced with a linen covering on the tail part and with a plywood (3 mm) covering on the nose part. The front part of the cabin was originally curved and glued out of veneer sheet, and in later "Muromets" it was multi-sided with a simultaneous increase in the glassed surface. Part of the glassed panel opened. The fuselage centers in later types of the "Muromets" reached 2.5 m in height and 1.8 m in width. The cabin volume reached 30 m^3.

The fuselage frame consisted of four ash longerons 50x50 mm in section in the front and middle parts (35x35 mm at the tail). Joining of longeron pieces was done with miter joints with furniture glue and wrapping with tape. The lateral elements of the frame are manufactured of pine and the braces were made out of piano wire, doubled throughout. The inside of the cabin was lined with plywood. The floor was made of plywood up to 10 mm in thickness. In the floor aft of the pilot's seats, there was usually a window with a thick glass for aiming devices. On the left side (or on both) behind the lower wing was a draw-away entry door. In the later types of the "Muromets" the fuselage was detachable behind the wing cell.

The horizontal stabilizer of the "Muromets" was load-bearing and had relatively very large dimensions -- up to 30% of the area of the wings, which is rarely encountered in airplane construction. The profile of the horizontal stabilizers with the elevators are similar to the profile of the

wings, but thinner. The stabilizer had two spars, the spars were box-type, rib spacing was 0.3 m and the rim was pine. The stabilizer was divided into independent halves, fastened to the upper longerons of the fuselage, to a four-sided cabane and to the top of the hook pyramid. The braces were wire and single.

There were usually three elevators: a center main one and two side ones. With the appearance of the rear firing point the side rotors were spread widely along the stabilizer, increased in dimensions and fitted with overhang compensation, and the middle rudder was eliminated.

The ailerons were present only on the upper wings, on its outer panels. Their chord comprised 1-1.5 m (from the rear spar). The control surface levers had a length of 0.4 m, and sometimes special tubing with braces up to 1.5 m long were added to these levers.

The undercarriage of the "Muromets" was fastened beneath the inboard engines and consisted of paired N-shaped struts with skids, in the spans of which were fastened wheels in pairs on short axles with rubber bungee-cord shock absorption on hinged shoes. The eight wheels were coupled in pairs with leather. A dual wheel with a very wide rim was obtained. The undercarriage was unnaturally low, but everyone was convinced that the unusually high, for the pilots, undercarriage might be a reason for an accident during a landing due to the difficulty in determining the distance from the ground.

The tail hook consisted of an ash beam with a section at the support of 80x100 mm and a length almost the height of a man. The upper end of the hook was fastened to a lateral fuselage brace with rubber bungee cord, and

on the lower end with a skid plate of considerable dimensions. In the first "Muromets" there were two parallel tail skids of smaller dimensions.

At rest, the fuselage occupied an almost horizontal position in view of this the wing was set at the very high angle of 8-9°. The position of the airplane during the flight was almost the same as on the ground. The angle of installation of the horizontal empennage was 5-6°. Therefore, even with the unusual layout of the airplane with the position of its center of gravity aft of the wing cell, there was a positive longitudinal V of about 3° in it and the airplane was stable.

The engines were installed on low vertical frames or on beams, consisting of ash shelves and braces, sometimes protected with plywood.

The fuel tanks -- brass, cylindrical, with sharpened streamlined ends, were usually suspended under the upper wing. The nose parts of them sometimes served as oil tanks. Sometimes the fuel tanks were flat and were located on the fuselage.

Control of the engines was separate and common. Besides the levers for controlling the throttle of each engine, there was one common " autolock " lever for simultaneously controlling all engines.

The control of the airplane was by cable. Originally a control frame was made and later it was a column. Control was always single. It was considered that if the pilot was killed or wounded, he could be replaced by another member of the crew, which subsequently happened more than once in a combat situation. The foot control was with pedals. The control wire was sometimes doubled in places.

The entire design of the airplane, like its layout, for 1913-1914 and to be recognized as leading, simple from a production standpoint and expedient.

Construction on the first copy of the "Il'ya Muromets" airplane was completed in October of 1913. The first factory flights, during which tests with the middle wings were conducted, were not totally successful. After the airplane could pass its testing, they began to make rating flights in it. A number of records was set. On the 12th of December, the "Il'ya Muromets" lifted a load of 1130 kg (the previous record on a Somer Airplane was 653 kg). The take-off run during test flights sometimes did not exceed 110 m[1]. I.I. Sikorskiy piloted the airplane. After a number of flights with various loads on 12 February 1914, a flight was made with sixteen passengers on board (and with a dog); the weight of the cargo lifted was 1290 kg[2]. During the course of February and March, several scores of flights with an overall duration of 23 hours were completed[3].

In the press of those years it was noted that during flight people could walk along its wings without disturbing the balance of the machine in the least in doing this. The stoppage of even two engines still does not foresee the machine to descend immediately. It can continue flight even with two engines working [4]. For those times all this was completely and heretofore unseen and made a great impression on participants and with eye witnesses of the flights.

However, regardless of the success, numerous flights showed that the power of the engines was insufficient.

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1 "Aero-and Automobile Life", 1914, No.1 (Chronicle)

2 Ibid, 1914, No. 4 (Chronicle)

3 Ibid, No.5

4 Ibid, No.8

Flights were conducted in winter, and the airplane was set on a ski undercarriage. The first skis in the world for a such a large airplane were built, having the shape of paired skids and were fastened on two cabanes each, with rubber bungee cord shock absorbtion. There were also two tail skid skis. The "Il'ya Muromets" seaplane (IM-B float)[1].

This was the first example of the "Il'ya Muromets" airplane (plant no. 107), installed on a float undercarriage upon the order of the naval department. Its four 100 hp "Argus" engines were replaced with two "Sal'mson" engines with 200 hp (inboard) and two "Argus" engines of 115 hp (outboard).

There were three floats: two main ones and a third on the tail (fig. 119). The main floats were fastened beneath the inboard engines to special undercarriage struts on rubber bungee cord shock absorbers. The cords were wound onto the crossing steel tubes, which connected the fastenings of both floats, and onto the tubes of the float cabane parallel to them. The floats were short, without steps and flat-bottomed, with low reserve buoyancy (about 1.3) and in type were similar to the floats of the S-5a airplane. They were made of plywood on an ash frame and were distinguished by their simplicity of construction. The airframe of the airplane remained the previous one and its design was strengthened.

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[1] TsGVIA, f.2008, op.1, d.724, l.6
K.A. Karillov, Materials of the historical department of the Main Naval Staff, 1947
[Translator's Note: Letter designations have been converted alphabetically throughout, i.e. original A=A Б = B, B=C Г =D, Д =E, E=F]

The first flight with a duration of 12 minutes was made on 14 May 1914[1]. Piloted by I. I. Sikorskiy and lieutenant G.I. Lavrov, the airplane successfully passed testing with a full load. Sea going capability was satisfactory, and controllability on the water was good, which was made favorable by the possibility for using the work of engines on either side for turns.

The "Muromets" in this variation was accepted by the navy department. This was the largest seaplane in the world right up to 1917. The Il'ya Muromets Kiev" (IM-B Kiev) and series B[2]. This air ship (this is what they began to call the "Muromets), the second in numbering, with factory number 128 (fig. 120) differed from the first with its smaller dimensions and more powerful power installation -- four "Argus" engines of 140 hp (the two inboard ones) and of 125 hp (the two outboard ones). The large increase in power with lower weight allowed several new world records to be immediately set.

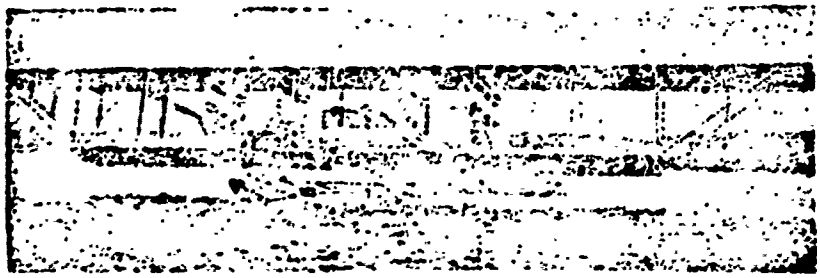

Fig. 119: Il'ya Muromets Airplane on Floats

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1 TsGVMA, f.843, d.14165

2 "Aero-and Automobile Life", 1914, No. 12, 13
The Petersburg-Kiev-Petersburg Flight, 1914

On 4 June 1914 -- a climb to an altitude of 2000 m with ten passengers on board. The flight of I. I. Sikorskiy took place over Pulkovo, Krasnoye Selo, Tsarskoye Selo and over the ocean for a period of one hour 27 minutes.

On 5 June -- the flight with five persons on board for a period of six hours 33 minutes, 10 seconds. Six hundred fifty versts were covered and thereby the record for duration of a flight was established.

16-17 June -- flight from Petersburg to Kiev with a landing in Oresh in 12 hours 15 minutes flight time and back with a landing in Novosokol'niki, for a total of 30 hours 30 minutes. The load during this flight amounted to 1610 kg: a crew of four persons (I. I. Sikorskiy, G.I. Lavrov, Kh.F. Prussis and V.S. Panasyuk, tools, spare parts and baggage for a total weight of 150 kg, 940 kg of gasoline and 260 kg of oil).

This airplane received the name "Il'ya Muromets Kiev" in honor of the flight. In 1915-1973 more airplanes were built which bore the name "Kiev Ship" and one replaced the other.

After sending this airplane to the war department in August of 1914, an "armament-machine gun platform" on it was removed, and installation of the armament was done later, already in the front. This airplane was in service for over two years, completed combat flights and then was used as a trainer and was written off in 1916[1].

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[1] TsGVIA, f.493,op.5, d.36, l.165

Airplane number 135, the same type as the "Kiev" with four 140 hp "Argus" engines was transferred to the war department on 31 August 1914. Both of them, together with the first "Muromets" and four subsequent ones received the general designation "Series B" (A indicated the "Russian Champion" airplane).

For the subsequent four series B airplanes, which corresponds in dimensions to the "Kiev", there were not enough "Argus" engines. The 10-12 engines in reserve were intended for airplanes of the next series C. It was necesary to install "Sal'mson" engines which were on hand. They were rotary type, the 14-cylinder 200 hp (the two inboard ones) and 9-cylinder 135 hp ones (the two outboard ones). There were no hoods or f. rings and these engines with their radiators and equipment gave high frontal drag. Therefore, regardless of the relatively high power, the speed, ceiling and load of these ships was lower than with the "Argus" engines.[1] Only student and training flights were conducted on the series B airplanes (fig. 121). In December of 1914, the airplanes produced were gathered into the "Escadrille of air ships". This was the first strategic aviation assemblage in the world.

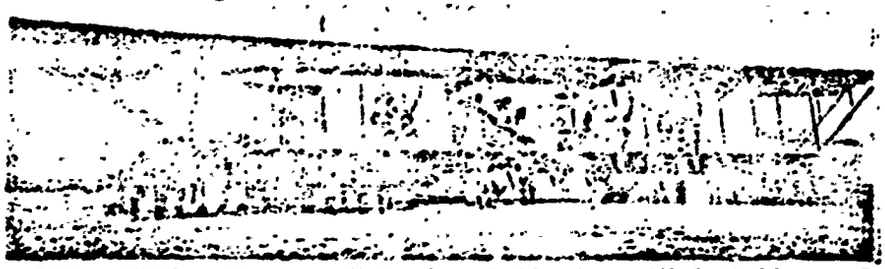

Fig. 121: "Il'ya Muromets" Series B Airplane With Sal'mson Engine

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[1] Ibid, f.493, op.4, d.425, l.73

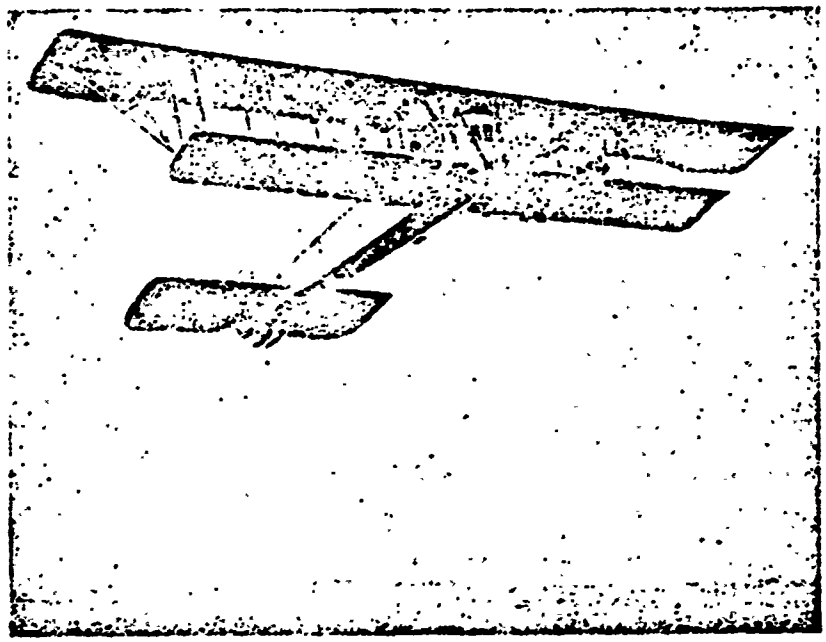

Fig. 120: "Il'ya Muromets Kiev" Airplane in Flight

The "Il'ya Muromets" series C (lightened combat, narrow-wing). After the first seven airplanes, the B series was discontinued; production was begun of the new series C airplanes, of significantly smaller dimensions and weight ("lightened combat"), and more applicable to combat usage. Their speed was significantly increased. The design remained generally the same as the previous one. The crew was also four persons.

The airplanes of this series (about 30 copies) underwent several changes in connection with military requirements. The initially round and blunt nose of the fuselage was made sharp, then multi-edged, while the glassed area constantly increased. A second door was made on the right side and a row of port holes were cut through. The fuel tanks were shifted to the fuselage beneath the wing center section and along the sides, so that in case of bullet puncture the leaking gasoline did not flow onto the engines. The oil tanks were located behind the engines. The outer edges of the wing began to be manufactured out of steel tubing with this series (before this they had been wooden).

The dimensions of the series C ships are given in fig. 118. The weight of the airplane was about 2000 kg, and with the power unit it was 2900-3150 kg depending on the type of engines. The name "narrow-wing" was given later, after the following series D with wider rings (the upper and then the lower) had already begun to be built.

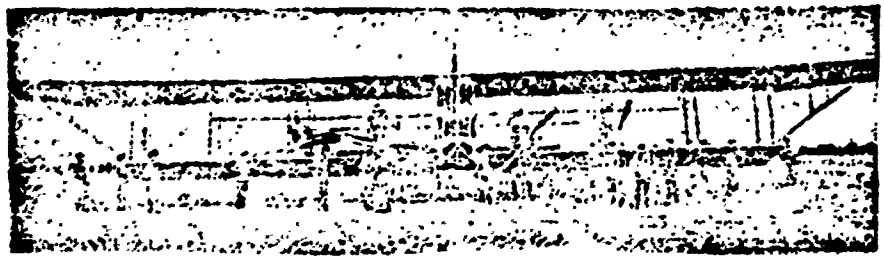

Fig. 122: "Il'ya Muromets" Series C Airplane ("Kiev ship")

A large part of the series C airplanes (apparently, 22 copies) was fitted with four "Sunbeam" 150 hp engines, but there were also other variations:

-- two 140 hp and two 125 hp "Argus" engines ("Kiev ship") (fig.122) and four "Argus" engines of 140 hp each. Both variations exceeded in their flight qualities the airplanes with "Sunbeam" engines, which actually yielded a total of 110-120 hp;

-- four RBZ-6 engines of 150 hp;

-- two "Sal'mson" engines of 200 hp;

-- two "Sunbeam" engines of 225 hp;

-- trainer variations, in which the "Sunbeam" engines were also installed with pusher propellers. In both of these, which was relatively unusual for "Il'ya Muromets" twin-engine modifications, the wing cell had a slightly (by 1-1.5 m) smaller span as a result of removal of the sections beneath the outboard engines. For training flights without the combat load the power of these two engines was sufficient (fig. 123).

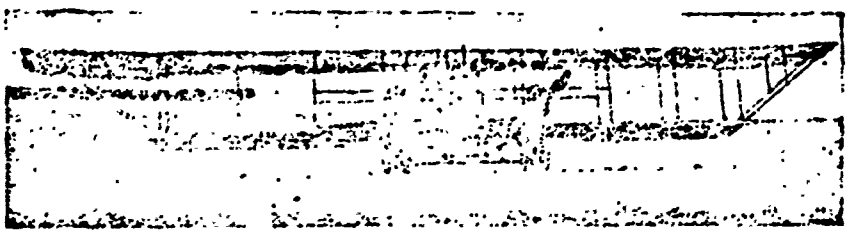

Fig. 123: "Il'ya Muromets" Series C Trainer Airplane With Two "Sunbeam" Engines of 225 hp With Tractor Propellers"

The "Kiev ship" had a glorious history. In 1950, 30 combat flights were performed on it with good results. Both this airplane and its crew (I.S. Bashko, M.V. Smirnov, G.G. Gorshkov and A.A. Naumov) were outstanding,

showing a graphic example of what could be obtained from mastery of military equipments.

In the spring of 1915 on ship no. 167 with RBZ-6 engine, the first test in the world was conducted of lifting and dropping a 25-pood bomb (410 kg), a size previously unseen. The test was absolutely successful. The bomb was a practice one (fig. 124). In practice even after this, bombs were used which weighed no more than 15 poods (rarely) and usually no more than 5 poods. A bomb was made weighing 40 poods (656 kg), but it was not dropped.

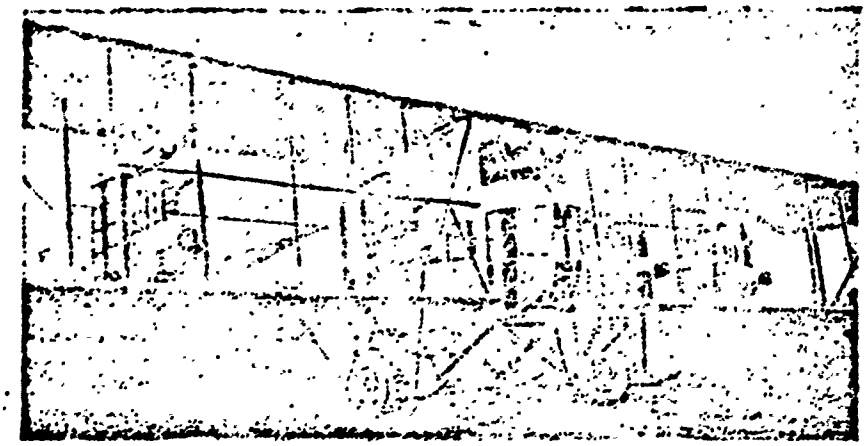

Fig. 124: "Il'ya Muromets" Series C Airplane with RBZ-6 Engines With a Suspended 25-Pood Bomb"

According to yet unsubstantiated documentary information, there was a "Il'ya Muromets" airplanes with four "Fiat" engines of 110 hp each, having frontal radiators.

The "Il'ya Muromets" series D[1]. These series D airplanes, whose output was begun in December of 1915, were distinguished from the Series C airplane with their somewhat larger dimensions and in particular by the

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1 TsGVIA, f.493,op.4, d.424, ll.29,63,66,80; op 10, d.46, 1.290; op 11, d.10, ll.15,131.

width (chord) of the upper wing (3.2 m) and the lower one (2.46-2.6 m). The crew was six persons. The weight of the airplane without the engines became 2800 kg. The following combinations of four engines were used: "Sunbeam" of 150 and 160 hp, "Argus" of 125 and 140 hp, "Berdmore" of 160 hp and RBZ-6 of 150 hp, and also two "Reno" of 220 hp with two RBZ-6 or "Sunbeam".

Fuel and oil consumption for the "Reno" with RBZ-6 was 176 kg/h, while for four "RBZ--6" engines it was 137 kg/h.

The "Il'ya Muromets" series D-1 (IM-G-1) was similar in design to the "Il'ya Muromets" series C, but differed from its predecessor in its less developed ailerons. The first copies were fitted with "Sunbeam" 150 hp engines; two of them were fitted with "Sunbeam" 160 hp engines [2]. On one of them, bearing the name "Kiev ships" (the second in numbering) four "Argus" engines of 140 hp each (or possibly two of 140 hp and two of 125 hp) removed from run-out airplanes were installed. At the end of 1916, the "RBZ-6" began to arrive and became the basic ones for the "Muromets" and were then used in combination with "Reno" engines of 200 hp or without them.

Some of the copies, begun as D-1, were in the course of construction changed into D-2, D-3 and D-4. One of the D-1 airplanes was transformed into a E-3 [3].

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1 Ibid, op.4, d.160, 11.168-169

2 Ibid, f.2008, op.1, d.512, 1.319; d.735, 1.73

3 Ibid, f.369, op.8, d.72, 1. 86

The "Il'ya Muromets" series D-2 ("Russo-Baltic strengthened wide-winged"). This series was begun in 1916 with the production of one copy. Then after the first series of D-3 and D-4 was continued in 1917-1918. A total of 8 copies were built[1].

These airplanes were distinguished from the series D-1 airplanes primarily by a single very important innovation -- a gunner's compartment "machine gun nest" in the end part of the fuselage. With this the fuselage design was still not changed and the gunner's compartment occupied the last, pointed in plan, section of the fuselage, which began from the aft spar of the horizontal stabilizer. Its dimensions were: length 0.8 m, width 0.6 m and height 0.7 m. This cabin, initially very crowded, was then enlarged. The machine gun stood on a spindle at the extreme rear point of the fuselage.

In connection with the appearance of this compartment, the vertical empennage was changed (fig. 125).

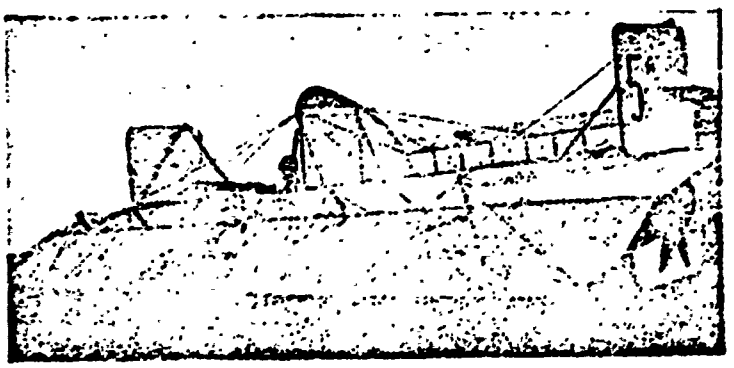

Fig. 125: Tail Machine Gun Compartment of the "Il'ya Muromets" Series D-2 Airplane

[1] TsGAKA, f.29, op.10, d.654, ll.137-138
"Journal of the Airfleet", 1921, No. 8-9, pp 14-15

On the first copy of the Series D-2 airplane was a flat-bottomed fuel tank, consisting of three sections and located on the top of the nose part of the fuselage. In the tank was a hole for exit of the gunner onto the upper platform. Behind the tank was a ferring out of aluminum and a hatch with a "Lewis" machine gun, which could be shifted from one side to the other.

They installed fuel tanks on airplanes of later production which were normal for the "Il'ya Muromets" -- cylindrical with streamlined ends -- between the wing center section and the fuselage, each holding 345 kg of gasoline. The wings were set an angle of 9 degrees and the engines at an angle of 4 degrees. The area of the ailerons was 14.5 m^2, that of the horizontal stabilizer was 24 m^2, that of the elevators was 11.5 m^2, and that of the rudders was 7 m^2. Armament consisted of five machine guns and 170 kg bombs.

In subsequent airplanes of this type, released already in 1918, the tail gunner's compartment was enlarged and lengthened.

On one of the airplanes of this series, bearing according to succession, the name "Kiev ship" (the third), four "Berdmore" 160 hp engines were installed.[1] In flight characteristics this airplane was the best of all "Muromets". In the beginning of 1917, with Captain I.S. Bashko at the controls, an altitude of 5200 m was reached with a total load of 1340 kg[2]. Its speed reached 137 km/h and its full load was 115 poods (1900 kg). It

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1 TsGVIA, f.2008, d 512, l.319

2 M.N. Nikol'skiy, Questions of Bomber Aviation Tactics, Aviation Press, 1925, page 70

was noted that the altitude of 5200 m was not the limit and the climb was stopped due to oxygen starvation of the crew.

The series D-2 airplanes worked through the entire civil war and after its end they were used on the first Moscow-Kharkov airline in the RSFSR [Russian Soviet Federate of Socialist Republics].

The airships with four "RBZ-6" engines were called the abbreviation "Russobalt" and those with two "Reno" and two "RBZ-6" were called the "Renobalt" regardless of their series. The dimensions and design of airplanes of the series usually remained without changes, since during the civil war, the RBZ-6 was installed sometimes simply because of the absence of "Reno" engines.

The "Il'ya Muromets" series D-3 ("Renobalt strengthened wide-wing") (fig. 126)[1]. Airplanes of this series, built in 1916-1918, where a further modification in the series D-2 airplanes with an increased combat capability.

Fig. 126: "Il'ya Muromets" Series D-3 Airplane in Flight

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[1] TsGVIA f.493, op.4, d.414, 11.304-305; d.424, 1.29; op.11, 1.10,11.153-154 f.2008, op. 1, d.512, 11. 14-15; d. 735, 1. 73
TsDAKA [Central State Archives of the Red Army), f.29, op.10, d.654, 11.139-140

Pivots were made for installing machine guns in the door holes, a hatch was made in the cabin floor for firing downward beneath the tail, and the tail machine gun nest was made wider and longer, extending beyond the rear edge of the control surfaces. The floor in the fuselage was built in such a way that a movable cassette for dropping bombs in the vertical position could be easily replaced with cassettes (benches) for dropping bombs in the horizontal position. The cabin was lengthened to the rear.

Two cylindrical fuel tanks were installed beneath the upper wing close to the center section, and the oil tanks were located next to the engines. In the first copies of the series D-3 airplanes, fuel tanks were located beneath the center section. Two rudders were installed at the ends of the horizontal stabilizer, and their area amounted to 26 m^2. Two vertical stabilizers were installed -- an upper and lower one -- along the axis of the airplane. The construction was welded out of tubing with a linen covering.

The cable control from the control frame ran outside in the front half of the fuselage, the frame from the internal wires in the previous series. The pedals were fitted with quadrants, which relieved the cable from extreme tension during high angles of rudder deflection.

The nose part of the fuselage was fully glassed. By comparison with the series D-2, the undercarriage and wing cell struts on the new series were strengthened. A third wire was introduced into the braces in the wing cell. As a result of all the strengthening, the weight of the airplane's airframe increased up to 2300 kg. Its rate of climb and ceiling

were lowered and its speed was changed little. Its armament consisted of six machine guns and 190 kg bombs. In all, eight copies were built (like the D-2), not quite identical, since these airplanes were produced over a period of two years. The last 2-3 copies came out in 1918, being assembled out of old components.

The "Il'ya Muromets" series D-4 ("Renobalt strengthened wide-wing')[1]. The construction of this airplane (1917-1918) was the result of a great deal of work on checking the strength of the "Muromets", which conducted in the Uvoflot. The series D-4 airplane was the direct development of the D-3 without any essential differences, but the margin on safety was brought up to 3.5 times, and in places up to 4.5 times; the weight of the ship increased a little by comparison with the later copies of the D-3. The improved D-4 airplane was tested in June and July of 1917 and was recognized as being fully suitable for series production.[2] Several copies were produced.

The "Il'ya Muromets" series E (DIM)[3]. The series E airplanes (three copies) were built in 1915-1916 during the interim between construction of the types D-1 and D-2 airplanes. Factory testing of the first airplane of this series was begun in January 1916. A feature of the two airplanes was their less than usual span and installation of four "Sunbeam" 150 hp engines in two tandems (fig. 127). The second airplane in order had a normal

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1 TsGVIA, f.493, op.4, d.441 (57), 11.146,150,155,172,201,205,217; op 10, d.46, 1.290, d.117, 1.4; op. 11, d.10, 11. 186,202,235, f.2008, op.1, d.512, 1.43; d.633, 1.33

2 Ibid, f.2008, d.633, 1.33

3 Ibid, f.493, op.11, d.10, 1.144; f.802, d.4874, 11.60-61 (diagram of overall view); f.2008, op.1, d.512, 1.100
TsGAKA f.29, op.10, d.654, 11.133-134

configuration -- with the engines in a row.

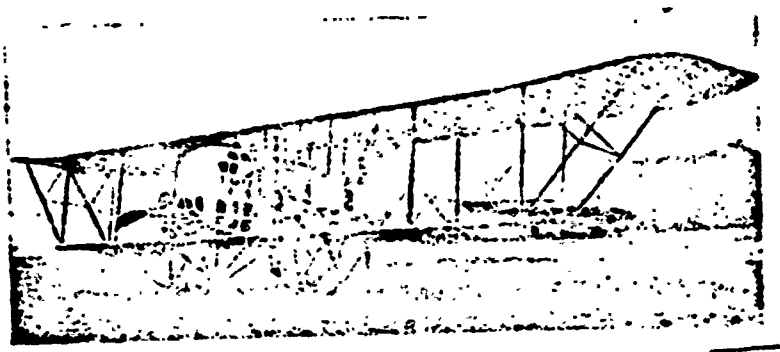

Fig. 127: "Il'ya Muromets" Series E (DIM) Airplane

In all three airplanes, an important design innovation was made for the first time in the world -- operational separation of fuselage. The front part of the fuselage made up a single unit with the "engine cage", i.e. the central part of the wing cell, including the power installations. The fuselage separation point was made behind the rear wing spars. The nose part of the fuselage was up to 2.5 m in height and was all glassed. In front and above were hatches for machine guns, and there was also a firing point behind the cabin. There was no more tail installation. The pilot's seat was located on the left. On his right was the seat of the artilleryman, under whose right hand was the lever for dropping bombs with a cable drive from him to the cassettes. There was also on the side a folding step -- a bench for the gunner.

The undercarriage was changed by comparison with the undercarriage of the series B,C and D. There were no guys and braces beneath the fuselage. The basic M-shaped struts were fastened to joining pipes beneath the struts at the engine installations. The undercarriage skids were normal, and additiona braces ran from their joining parts to the joining parts for fastening the lower wings onto the fuselage.

Flat-bottomed fuel tanks, consisting of three sections, lay on the fuselage and due to their shape were streamlined by its nose part. There were three rudders. Control of the elevators was accomplished through lateral levers and instead of a control frame a control column was installed. The cable drive from the pedals to the rudders ran along the ceiling of the cabin and fuselage. The levers on the ailerons were fitted with quadrants.

The second series E airplane differed from the first by a lengthening of the fuselage by one cell and an increase in wing span by one cell on each side. There were two rudders and a tail gunner's position.

The series E airplanes with tandem power installations do not have success and were not accepted. The losses in thrust, especially on the rear propellers, were extremely high. The slight lengthening of the wings was also harmful. The quality of the airplane proved to be poor: its take-off run was greatly increased, the ceiling was no higher than 200 m with a light load (a crew of three persons), and combat load was absent. The total of two flights were completed. The airplane with engines installed in a row in the lower wing behaved normally, like the series C machines with the same engines. The E series was stopped after ten copies.

The "Il'ya Muromets" series F [1]. From a design standpoint this type of airplane was similar to the type E machines, but its layout was normal, with the engines in a row, and the dimensions were significantly larger than in all the other types of "Muromets". Four "Reno" engines of 220 hp each

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1 TsGVIA, f.493, op.4, d.160, 11.163-169; d.424, 1.29; f.2008, op.1, d.512, 11.14-15, 325 (test report); op.2, d. 626, 1. 309.
TsGAKA, f.29, op.10, d.654, 11. 145-146

were installed normally in a row, and the nose part of the cabin was fully glassed. No less than eight copies of the series F airplanes were built in two modifications: the F-1 and F-2, which differed from each other significantly. With this the designation F-1 arose only when the type F-2 appeared, and before that there was a single designation F.

The first series F airplane passed testing in Pskov, was recognized as fully suitable for combat flights, although it was demanding during landings, and was accepted (fig. 128).

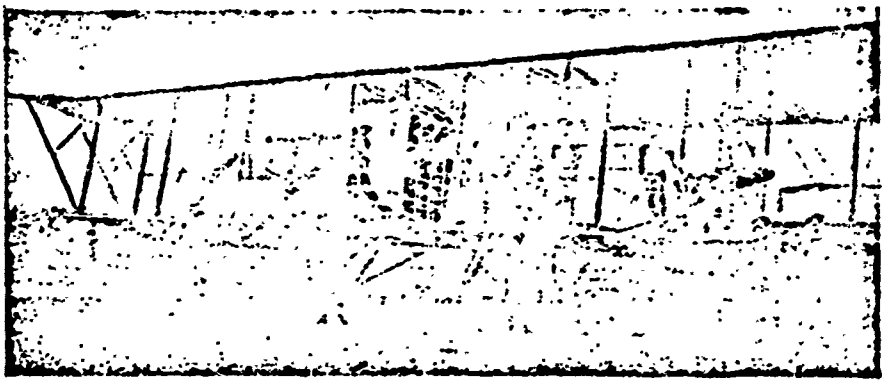

Fig. 128: "Il'ya Muromets" Series F Airplane (1st copy)

Of the design features in the series F airplanes, it should be noted that the aileron control was changed for the purpose of decreasing effort on the control column and the levers on the ailerons were significantly lengthened and made out of welded tubing. The remaining controls and installation of the tanks was like in the series E. The undercarriage was the same as in the series E, but with wire tensioners beneath the fuselage. The wheels are of the heavy type with dimensions of 670x100 mm, were double rimmed, for a total of eight wheels in four pairs. In the first copy of the airplane, there was no more tail gunner's compartment, but a platform which lowered down (on cables) was installed in the floor behind the wing

cell for firing to the rear ("crow's nest"), and the machine gun was also lowered on a special installation together with the platform on which the gunner lay. The bomb cassettes were vertical. In machines of subsequent manufacture, the bomb cassettes -- only for dropping bombs -- were horizontal.

The first series F airplane differed from subsequent ones in its dimensions and weight. The airframe weight of the S-1 was 2825 kg, the weight of the four "Reno" engines was 1662 kg, the weight of the radiator was 138 kg, and empty weight was 4960 kg. The armament was increased up to 8 machine guns; two "Vickers" with 1200-1500 cartridges, three "Lewis" with 940-1700 cartridges and three "Madsen" with 750-1000 cartridges. On the first airplane there were only five machine guns, which weighed together with their cartridge reserve 320 kg. The crew was 7-8 persons.

Of the series F machines, two airplanes (those of Nizhevskiy and Alekhnovich)[1] were accepted and completed military flights beginning in spring of 1917, not counting the first one, which was accepted in 1916. There are only some recollections relative to series F-2 airplanes in the archive material[2]. This is explained by the fact that airplanes of this series were built in 1917 and did not get to the front. There were two or three copies of them and at least one of them passed factory testing. The fuel tanks in them were installed on the wing center section, there was a tail gunner's installation and two rudders without a middle vertical stabilizer, which was in the series F-1. In the side walls of the rear gunner's cabin were windows for

1 TsGVIA, f.2008, op.1, d. 512, 11.100-103

2 Ibid, f.493, op.4, d.160, 11.168-169; op. 10, d.117, 1.4

observation. Armament consisted of seven machine guns with 4000 cartridges.

The series F-2 "Muromets" were the largest among airships from those times. There were no airplanes which were equal to them in load capacity. Besides this, they possessed highly improved gunner's protection.

It is very difficult to compile a full listing of the "Muromets" airplanes, since a large part of the archives of the document were not preserved. There are no full drawings, and only single sheets and diagrams. There are data indicating that up to 80 examples of these airplanes were built.

Strength of the "Il'ya Muromets" airplanes and their overall design and aerodynamic evaluation. Questions of the overall strength of the "Il'ya Muromets" airplane during the first time arouse little interest in aviators. Attention was concentrated basically on local strength, for instance, on the strength of the undercarriage during landing. True, sometimes fliers expressed doubt as to the strength of the "Muromets", but they could not found this doubt and continued to fly.

The first warning occurred unexpectedly. On 16 May 1916 in Dskov, a "Il'ya Muromets" airplane, accomplishing a flight in a circle above the airplane, during an approach to a landing suddenly went into a descent and with the engines running plowed into the ground. From the ground was observed that while still in the air, the fuselage of the airplane broke off near the tail empennage[1]. Three persons among the crew were killed and the fourth was saved, having been in the rear part of the cabin. According to his words[2],

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1 According to the data of A. N. Ozeretskiy -- witness to the accident and M.N. Nikol'skiy

2

the catastrophe occurred as if due to sudden insanity of the pilot, who suddenly thrust the control column away from him and opened and the throttle all the way 200 meters off the ground. The two others did not succeed in righting the airplane.

This case could not be the basis for judging the strength of the airplane, since the fuselage may have been broken at the high speed during the descent and the extreme overload on the empennage, however, this fact left a deep impression on all and they began to talk about it. They recalled that the fuselage of the "Muromets" did not possess any special rigidity and that in flight, significant twisting was observed, sometimes reaching an angle of 5-7 degrees and was very noticeable along the empennage. They also recalled that there were cases in which the fuselage longerons delaminated at the butt joints, where the wood was connected with a miter joint[1].

Doubts arose relative to the preservation of the wood and linen. The series D, E and F airplanes were tested at that time, since they were usually stored under the open sky and frequently got wet.

Nevertheless, throughout the course of 1916, the "Muromets" continued to accomplish multitudinous combat flights.

As the overall state of art of airplane building developed, deeper studies began on aerodynamics and especially on questions of airplane strength. The calculation and testing bureau under the direction of N. Ye. Zhukovskiy conducted checking calculations for strength of combat airplanes which were built in Russian plants according to foreign and domestic models.

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1 TsGVIA, f.2008, d.512, l.29

This also touch the "Muromets". The Uvoflot raised the question on checking their strength and the Technical Committee of the Uvoflot was charged with doing this. In the beginning of 1917, a commission was made to check the strength and aerodynamic evaluation of the series D "Muromets". The best forces at that time were attracted to the commission -- Professor S.P. Timoshenko, A.P. Fan-der-Flit (chairman) and G. A. Botezat.

The commission began its work with a familiarization with drawings and calculation data requested by it at the factory. It became clear that aerodynamic calculations and full calculations of strength of the airplane were just not done by the factory.[1] Much was done on testing plans and structure of previous airplanes. The commission reported to the technical committee on the results of its work on 16,20 and 23 May 1917.[2] The conclusion made by the commission voiced the fact that the "margin of safety of the "Muromets" was two times less than in the weakest small machines".

According to the calculations of the commission, some parts and components of the series D "Muromets" have a safety margin of 2.4-2.8. And although much in these calculations was arguable and unclear, the commission drew the conclusion that sharp evolutions on the airplane were inadmissible and that in general, flights in them were dangerous. A number of recommendations were made concerning reinforcement of the struts and guys of the wing cell (the wing spars and fuselage longerons did not raise any doubs). After this the margin of safety of all series D, E and F airplanes built was raised

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1 TsGVIA,f. of the Uvoflot, op. 4, d.424, 11. 76-77

2 Ibid, f.2008, op. 1, d.512, 11.35-38

to 3.5 - 4.0, and in certain components up to 4.5 .

Many years have passed since that time and now the question as to whether or not the "Muromets" were strong can be answered in the affirmative. Much speaks for this. "Muromets" performed their tasks in combat flights successfully, performing during these evolutions -- turns and rolls -- normally, and the airplanes did not break apart in the air. They were not made overweight and their load ratio amounted to 30-34%. Some lack of rigidity under flexion and torsion was natural for airplanes of such large dimensions and with its elimination the load ratio would have been reduced.

It can be asserted that the "Muromets" as engineering constructions were highly perfected, in a sense of rational utilization of material and economy of weight. The presence of large angles of torsion only supports this. For 1913-1915, when the science of airplane construction strength was only being developed, "Muromets", at least up to the series C, were indeed marvels of aviation engineering, speaking of the talent of their designer. In order to judge the level of science of the strength of aviation designs of those years, suffice it to say that even such authorities in the area of construction mechanics as Professors Stepan Prokof'yevich Timonshenko in airplane calculations admitted the even distribution of weight along the area of wings and drew on this basis the conclusion of lack of strength in the "Muromets". They still did not have a clear concept about air dynamic loading of the wings of an airplane and about its distribution along the chord and along the span in different cases of loading. The cases A, B, C and others were not yet formulated, strength

norms had not been compiled into laws and they still were only being groped for and established during checking of airplanes already built. Here, practice went before theory.

The requirement of the Technical Committee on bringing the strength of the "Muromets" somehow up to the level of the weakest of the small machines was not sufficiently founded. Already during the war the coefficients of failure-producing overload had been noted: for fighters it was 12, for reconnaissance planes and trainers it was 8 and for the largest airplanes it was 3-4.

Selection of the layout for the "Muromets" was also done properly. Installation of the engines along the wing in a row, long wing length and an enclosed overall streamlined cabin in the fuselage were successful solutions. The layout of the airplane with a long tail, load-bearing horizontal stabilizer and multi-strut wing cell was up to that time unavoidable and fully justified. Making the center of gravity of such a large airplane at one third the chord of the wing with relatively low-power and light engine would hardly have been possible.

Up to 1915 the layout of the "Muromets" was the leading one, and the move away from it began in 1916. Only in 1917, when it had ceased to satisfy the increasing requirements of aerodynamics, did it become an insurmountable obstacle in the path of increasing the flight quality of these airplanes and it was finally dated. Increasing power caused an increase in fuel reserve, and an increase in dimensions and weight of the airplane. The speed was almost not increased, and the b_{omb} load was constantly decreased, coming down to the laughable figure of 150-200 kg of bombs with

seven ton gross weight of the airplane. The value of "Muromets" of series D and F as bombers was reduced almost to zero on a four hour flight. An increase in the weight of the bombs by means of shortening flight duration limited the radius of operation and deprived the airplane of the possibility of operating somewhat deep in the enemy's rear.

Series D and F "Muromets" were used in the civil war and for some time after its termination. Improvement made on the airplane were not essential and had a one-sided character: improvements in one direction brought with them difficulties in other directions and in the final analysis helped little.

The qualities of the series D and F "Muromets" in 1917 can be judged by means of comparing them with the closest foreign airplanes of that year.

The Germans in 1917 still do not have any large airplanes which were equal in quality to the "Muromets", although there were larger ones[1]. The French and Americans were simply building them at that time. The English, however, in the summer of 1917, had in their armament the series-produced "Handley-Page" bomber with two "Rolls-Royce" engines of 275 hp each. In dimensions and weight it coincided almost precisely with the series D "Muromets" (the thought even arises of the English borrowing the basic parameters of the airplane): the span of the upper wing was 30.5 m, wing area was 152.6 m^2, empty weight was 3850 kg and flying weight was 6370 kg. However, with less power it gave the same speed of 128 km/h, while its flight duration amounted to 8 hours and range up to 1000 km with a bomb load of 800 kg. All this was due to the better layout.

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[1] E. Offermann, Risenflugzeuge, Berlin, 1923

Armament of the "Il'ya Muromets" airplanes. The first practical step in equipping "Muromets" with firing armament was the elimination of the firing-machine gun platform with the 37 mm Hotchkiss gun on it, which did not justify itself. In the beginning of 1915, instead of it a gunner's position was installed in the wing center section (in series B airplanes) (fig. 129), providing fire coverage of the entire upper hemisphere. The gunner was located between the center section spars, the ribs and covering were removed and he could sit on the fuel tank and fire from two machine guns. Sometimes two gunners were located on the airplane. The vertical intervals from the center section to the fuselage were covered with linen, and thereby the harm from a possible increase in induced drag was almost eliminated. There was a hatch in the ceiling of the fuselage for exit upward. Units with bushing-sockets for the machine gun spindle pin were installed on the center section spars. Later, brackets with a socket for the pin of the "Maxim" gun, and sometimes movable ones were installed in doors and in windows for firing from the side. Sometimes a hatch was made in the ceiling of the fuselage behind the wing center section, and in it lateral rails or a sector were installed, along which rode a carriage with a socket for the pin of a machine gun, which had belt feeding in this case. The machine gun was a "lightened Maxim".

In some cases, for protecting the airplane from below and from behind, it was equipped with a "crow's nest" which was a platform which lowered from the fuselage on cable using a winch, which had a length of about 2 m on which the gunner lay, having the machine gun in front of him and beneath the tail of the airplane, and also lowered on a special bracket. The front edge of the platform was fastened on hinges to the cabin floor. More frequently a

similar installation was made simplified. A gunner lay on the cabin floor and before him lowered only a hatch on machine gun which opened backward.

The gunner's position in the tail of the fuselage appeared in the "Muromets" of series D, E and F only in 1916, thereby providing fire coverage backward. Together with it, a nose installation was also fitted (in front of the pilot, just to the right), having the appearance of a vertical slat into which was fastened a machine gun on a hinge with firing angles of 25° to the sides and 60° upward and downward. Finally, series F ships were equipped with a hatch and machine gun in the ceiling of the front part of the cabin in front of the wing center section. The number of gunner's positions reached eight. Thus, with successive measures, full spherical, or so-called "ball" fire coverage was achieved, and was accomplished for the first time in the world on a "Muromets". But this was done only by 1917, while in 1915-1916 only the installation in the center section and firing through the windows was used. However, with a crew of four persons this was sufficient. On a series F airplane, the crew consisted of 7-8 persons.

A "railway" consisting of two angle sections along which a cart rolled on rollers, ran to the gunner's nest in the tail part of the fuselage. The gunner lay on the cart and moved, pulling himself with his hands by the bracing crosspieces. Staying in the rear cabin all the time was almost impossible: during flight it was very bumpy, and during landing the jerks were too strong. Therefore, the gunner moved to the tail only upon the danger signal.

Simultaneously with the beginning of work on arming the "Muromets" (1914) attempts were undertaken to dress the gunner on the platform in armor, for which special laths (armor) out of 2 mm tempered steel were manufactured at the Putilovskiy plant. There were attempts to armor the fuel tanks and pilot's seat, but they were rapidly stopped, since the weight balance of the airplane did not allow this, and the laths, like the platform, proved to be unnecessary.

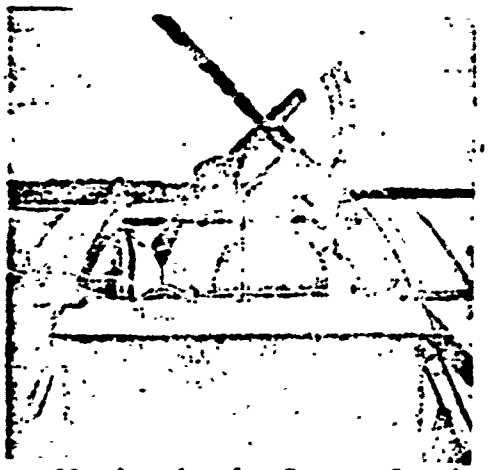

Fig. 129: Gunner's Installation in the Center Section of the Series C "Muromets" On the Front Spar a "Lewis" Machine Gun, and on the Rear One a "Madsen" Machine Gun

Curious experiments with a recoiless cannon of the system of Lieutenant Colonel Gel'vig and Captain Oranovskiy were conducted in 1915, for the first time in the world. The cannon consisted of a combination of two internal barrels of a three-inch field gun, connected at their ends (in tandem), with an overall length of about 4 meters. One barrel was a normal rifled one for the projectile, and the other with a smooth one for the wadding; there was no lock and the barrel was open at both ends. Firing occurred without any recoil. The cannon was installed on the rear spar

of the wing center section. Several shots were fired on the ground and two shots were fired in the air. However, the clumsiness of the cannon prevented its practical utilization.

The bombing armament of the "Muromets" also had to be created without any previous experience. The large dimensions of the cabin allowed the bombs to be located in the fuselage and for their internal suspension to be made. The installation for vertical suspension of bombs in the series B "Muromets" was already done for the first time in the world in 1914, and in the beginning of 1915 it was done on series C airplanes. The first series C "Muromets" with "Argus" engines could carry up to 30-poods (410 kg) of various bombs, each weighing from ten pounds up to two poods (33 kg), usually with 25 pounds (10 kg) and one pood (16.4 kg) on internal suspension. The five, ten and fifteen pood bombs were suspended outside, as was the 25-pood bomb (see fig. 124) which was made here in 1915, also the first in the world, since nowhere abroad were there yet airplanes capable of carrying such a bomb.

With the internal suspensions, the bombs were originally suspended vertically along the sides immediately behind the pilot's seat. Between the rows of bombs remained a relatively wide passage, sometimes occupied with small bombs, lying directly on the floor and tied down to it. Suspension was effected by the hook on the tail of the bomb on special brackets. Later they began to make vertical shelf-cassettes with horizontal suspension of bombs, for which the possibility was provided for dropping bombs singly or in a cluster.

Dropping of bombs was originally done by turning a handle, and smaller

ones simply from the hand. In 1916, an electric release (ESBR) was practically used for the first time in the world on these airplanes. All work on gunnery and bombing armament was basically done in escadrille workshops. The leading one was the collective of the number 5 ship of G. V. Alekhnovich. The installation described above were first developed and effected on this ship, and then were given in various combinations to other ships.

The bodies of the bombs for "Muromets" were manufactured primarily in workshops of the Moscow Technical Training School.

In 1914-1915, in conditions of the absence of antiaircraft artillery and fighters on the part of the enemy, the crews of the "Muromets" used the simplest fighting devices very well, making a number of hits on the target, with which the bombing was frequently exceptionally successful and it was done only in the plane of the wind. Cases were noted of strike on targets which were small in dimensions: roads, rolling stock, convoys, buildings, trenches and others.

With the appearance of a significant quantity of antiaircraft artillery and fighters on the part of the Germans, the possibility for the "Muromets" was to make several attacks on the target and then determine the sighting adjustment was gradually made more difficult. The necessity arose for emerging on the target and bombing from any direction, and not only along the wind. The works of A. N. Zhuravchenko[1] in cooperation with other artillery experts and with ship Commander G.V. Alekhnovich gave a new direction to the

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[1] Aleksandr Nikolayevich Zhuravchenko in 1914-1916 -- an artillery officer from 1917-- a pilot in the "Il'ya Muromets" airship escadrille. Later a professor, devoted activist in science and engineering. Died in 1964.

matter of accurate bombing and raised it to a level which was high for those times.

All subsequent theories of precision bombing and all instruments for this purpose, regardless of their design and complexity, to one degree or another are based on the principles developed by A. N. Zhuravchenko. Our priority in this matter is commonly recognized.

The attempt to use the "Il'ya Muromets" airplane as a torpedo carrier should be recalled. In the spring of 1917, the navy department turned to the Uvoflot with a petition to transfer to it a detachment of "Muromets", which it proposed to arm with torpedo apparatuses and use for torpedo attacks. In the end of July 1917 a torpedo apparatus was installed on one of the airplanes. It was noted that the center of gravity of the torpedoes shifted to 1.5 m aft of the center of gravity of the airplane[1]. However, factory testing dragged on and acceptance of this airplane did not take place.

In the history of Russian airplane building, the "Muromets" are one of the brightest pages and an object of our legitimate pride. They were original and their creation is a priority of our country in the area of construction of large airplanes, their armament, equipment and combat use.

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[1] TsGAKA, f.28, op. 1, d.19, 11.124-125

"Il'ya Muromets" Airplane

Table 10

a Год выпуска	b Самолет (заводской номер)	c Двигатели	Мощность л.с.	Размах крыльев верх. / ниж. м	Длина самолета м	Площадь крыльев м²	Вес пустого кг	Топливо и масло кг	Полная нагрузка кг	Вес полетный кг	Удельная нагрузка: на кр. кг/м²	Удельная нагрузка: на мощность кг/л.с.
1 1913	„Гранд" („Большой Балтийский")	2 „Аргус" 37	100	27,0 / 20,0	20,0	120	2000	150	400	3400	28,5	34
2 1913	Он же	4 „Аргус" "	100	27,0 / 20,0	20,0	120	3400	250	600	4000	33	21
3 1913	„Русский витязь"	4 „Аргус" "	100	27,0 / 20,0	20,0	120	3500	250	700	4200	35	21,5
4 1913	„Илья Муромец" (№ 107)	4 „Аргус" "	100	32,0 / 22,0	22,0	182	3800	334	1300	5100	28	13,8
5 1913	ИМ со средним крылом № 107	4 „Аргус" "	100	32,0 / 16 (ср)	22,0	210	4000	284	1500	5500	26	14,8
6 1914	ИМ гидросамолет (№ 107)	2 „Сальмсон" 38 / 2 „Аргус" 37	200 / 115	32,6 / 22,0	23,5	182	4500	900	1500	6300	34,5	19
7 1914	„Илья Муромец Киевский" (№ 125)	2 „Аргус" " / 2 „Аргус" "	140 / 125	30,95 / 22,45	19,0	150	3940	700	1610	4650	31	8,6
8 1914	ИМ-Б (№ 135)	4 „Аргус" "	140	30,95 / 22,45	19,0	150	3100	700	1500	4600	30,7	8,3
9 1914	ИМ-Б (№ 136—139)	2 „Сальмсон" 38 / 2 „Сальмсон" "	200 / 135	30,95 / 22,45	19,0	150	3900	700	1200	4600	32	7,2
10 1914	ИМ-В „Корабль Киевский" (№ 143)	2 „Аргус" 37 / 2 „Аргус" "	140 / 125	29,8 / 21,0	17,1	125	2900	550	1500	4450	35,3	8,3
11 1915	ИМ-В (№ 151)	4 „Аргус" "	140	29,8 / 21,0	17,1	125	2950	550	1500	4450	35,5	8,1
12 1915	ИМ-В (№ 150, 157)	2 „Сальмсон" 38	200	23,0 / 19,2	17,1	120	2700	400	800	3500	29	8,8
13 1915	ИМ-В (№ 159, 161)	2 „Сальмс" 38	225	23,0 / 19,2	17,1	120	2800	400	800	3600	30	8
14 1915	ИМ-В 6-местный, увеличенный	4 „Сальмс" "	150	29,8 / 21,0	17,5	125	3150	650	1450	4600	36,8	7,7
15 1915	ИМ-В учебный	2 „Сальмс" "	150	23,0 / 19,2	17,1	120	2700	300	700	3700	27	10,7
16 1915	ИМ-В (№ 157, В-21)	4 РБЗ-6 40	150	29,8 / 21,0	17,5	125	3500	600	1500	5000	40	8,3
17 1915	ИМ-В широкохватный (№ 179, В-33)	4 „Сальмс" 39	150	30,87 / 22,0	17,1	143	3900	600	1300	5100	34,5	8,5
18 1915	ИМГ-1 (№ 193)	4 „Сальмс" "	150	30,87 / 22,0	17,1	143	3500	650	1300	5100	34,5	8,5
19 1915	ИМГ-1 (№ 197)	4 „Аргус" 37	125	30,87 / 22,0	17,1	143	3700	500	1500	5200	35,1	10,4
20 1916	ИМГ-1 (№ 190, Г-44)	4 „Аргус" "	140	30,87 / 22,0	17,1	143	3750	550	1600	5350	36,2	9,6
21 1916	ИМГ-1	4 „Сальмс" 39	150	30,87 / 22,0	17,1	143	3500	650	1250	5400	36,5	8,4
22 1916	ИМГ-2 „Руссобалт"	4 РБЗ-6 40	150	30,87 / 22,0	17,1	159,6	3900	650	1200	5800	39,2	8,8
23 1916	ИМГ-2	2 „Рено" 41 / 2 РБЗ-6 40	220 / 150	30,87 / 22,0	17,1	159,6	3690	740	1160	5600	34,5	7,6
24 1916	ИМГ-2 „Корабль Киевский" (3)	4 „Бердмор" 42	150	30,87 / 22,0	17,1	159,6	3400	646+57	1200	5000	34,5	8,6

Table 10

Длина самолета h м	Площадь крыльев i м²	Вес пустого j кг	Топлива и масла k кг	Полная нагрузка l кг	Вес полетный m кг	n Удельная нагрузка: на крыло o кг/м²	n Удельная нагрузка: на мощность p кг/л.с.	Посадочная отдача q %	Скорость максимальная у земли r км/час	Скорость посадочная s км/час	t Время набора высоты в мин: 1000 м	2000 м	3000 м	Потолок практический u м	Продолжительность полета v час	Дальность полета w км	x Разбег м/сек	y Пробег м/сек
20,0	120	2000	150	400	3400	28,5	18	12	80	65	—	—	—	100	2	150	650	150
20,0	120	3400	250	600	4000	33	11	15	90	70	—	—	—	800	2	170	400	200
20,0	120	3500	250	700	4200	35	11,5	17	90	70	—	—	—	600	2	170	350	200
22,0	182	3800	334	1100	5100	28	13,8	25	95	75	25	—	—	1500	3	270	300	200
22,0	218	4000	354	1300	5500	26	14,5	27	85	70	—	—	—	800	3	250	450	200
23,5	182	4500	900	1500	6000	34,5	15	21	90	75	20	60	—	2000	6	550	500	180
19,0	150	3040	700	1610	4650	31	8,6	31,5	100	75	15	35	70	3000	5	500	—	—
19,0	150	3100	700	1550	4700	30,7	8,5	22	105	75	13	30	—	3000	5	520	—	—
19,0	150	3100	700	1300	4500	28	7,2	26	95	75	20	70	—	2000	4	350	—	—
17,1	125	2900	550	1550	4400	35,3	8,8	24	100	75	12	25	55	3500	5,3	650	200 (17 м/с)	200
17,1	125	2950	550	1300	4150	33,5	8,1	31	105	75	11	25	—	3700	5,3	650	220 (17 м/с)	200
17,1	120	2700	400	800	3500	29	8,6	23	100	70	—	—	—	—	—	—	—	—
17,1	110	2600	400	800	3600	30	8	22	105	70	—	—	—	—	—	—	—	—
17,5	125	3150	600	1450	4600	36,8	7,7	3,5	110	73	16	40	—	2900	4	440	420	220
17,1	120	2800	300	750	3200	27	10,7	22	90	70	—	—	—	—	—	—	400	180
17,5	125	3500	600	1850	5000	40	8,3	30	120	75	9	20	45	3500	4,5	—	—	—
17,1	143	3500	600	1300	5100	34,5	8,5	25,5	110	75	—	—	—	—	—	—	—	—
17,1	148	3500	600	1300	5100	34,5	8,5	25,5	110	75	—	—	—	—	4	440	450	250
17,1	145	3700	550	1500	5200	35,1	10,4	29	120	75	—	—	—	—	—	—	—	250
17,1	143	3750	550	1600	5350	36,2	9,6	30	125	75	—	—	—	—	—	—	—	—
17,1	143	3900	600	1550	5400	36,5	8,4	29,5	125	75	8	18	35	4300	4	500	—	300
17,1	159,5	3800	600	1500	5300	30,7	8,8	28,3	115	75	—	—	—	—	4	460	—	—
17,1	159,6	3800	740	1700	5500	34,5	7,4	31	120	75	9	20	40	3500	4	480	—	—
17,1	159,6	3400	444+8*	1700	5500	34,5	8,6	31	115	75	6	14	30	4000	4	540	350	250

Table 10

Reproduced from best available copy.

a	b	c	d	e		h	i	j	k	l	m	n		q	r
Год выпуска	Самолет (заводской номер)	Двигатели	Мощность л. с.	Размах крыльев верхн.	нижн.	Длина самолета м	Площадь крыльев м²	Вес пустого кг	Топливо и масло кг	Полная нагрузка кг	Вес полетный кг	Удельная нагрузка: на крыло кг/м²	на мощность кг/л. с.	Посадочная скорость км/ч	Скорость макс.
25 1916	НМГ-2	2 РБЗ-6 40 2 „Сальмсон" 39	150 130	30,87	22,0	17,1	159,6	3800	600	1470	5300	33	8,8	27,3	111
26 1916	НМГ-3 „Ренобалт"	2 „Рено" 41 2 РБЗ-6 40	220 150	30,87	22,0	17,1	159,6	3800	850	1600	5400	33,8	7,3	29,6	111
27 1916	НМГ-3	2 „Рено" 41 2 „Сальмсон" 39	220 150	30,87	22,0	17,1	159,6	3800	850	1500	5300	33,1	7,2	23,3	111
28 1917	НМГ-3 „Ренобалт усиленный"	2 „Рено" 41 2 РБЗ-6 40	220 150	30,87	22,0	17,1	159,6	4070	686+57	1530	5600	35	7,6	27,3	115
29 1917	НМГ-2 усиленный	2 „Рено" 41 2 РБЗ-6 40	220 150	30,87	22,0	17,1	159,6	3800	686+57	1500	5301	33,2	7,16	28,3	120
30 1917	НМГ-4 усиленный	2 „Рено" 41 2 РБЗ-6 40	220 150	30,87	22,0	17,1	159,6	3900	686+57	1500	5400	33,8	7,3	28	123
31 1916	НМД-1 (ДНМ)	4 „Сальмсон" 39	150	21,9	17,6	15,5	132	3150	690	1250	4400	33,2	7,3	25,4	120
32 1916	НМД-2	4 „Сальмсон" "	150	29,7		17	148	3800	540+160	1100	5300	35,5	8,5	27	110
33 1916	НМЕ опытный	4 „Рено" 41	220	33,0	27,0	17,1	190	4620	540+160	2000	6620	32,6	7,05	32,2	130
34 1916	НМЕ-1	4 „Рено" "	220	31,35	21,0	18,2	200	4800	930+130	2200	7000	35	8	29	130
35 1917	НМЕ-2	4 „Рено" "	220	34,5	26,6	18,8	220	5000	930+130	2400	7400	34,2	8,5	33	130
36 1915	НМЕ	4 „Рено" "	220	30,4	21,1	18,5	190	4200	—	1900	6100	32	8,9	31,2	137

Key:
a--Year of Production
b--Airplane (Factory No.)
c--Engines
d--Power, hp
e--Wing span
f--Upper
g--Lower
h--Length of airplane,m
i--Wing area, m^2
j--Empty weight,kg
k--Fuel and Oil, kg
l--Full load, kg
m--Flying weight,kg
n--Specific loading,
o--On the wing,kg/m^2
p--On power, kg/hp
q--Load ratio
r--Maximum speed near the ground, km/h
s--Landing speed, km/h
t--Time for climbing to altitude in min.
u--Service ceiling, m
v--Duration of flight, h
w--Flight range, km
x--Take-off run m/sec
y--rollout, m/sec

Table 10

h Длина самолета м	i Площадь крыла м²	j Вес пустого кг	k Топливо и масло кг	l Полная нагрузка кг	m Вес полетный кг	n Удельная нагрузка: o на крыло кг/м²	n Удельная нагрузка: p на мощность кг/л.с.	q Посадочная скорость км/час	r Скорость максимальная у земли км/час	s Скорость посадочная км/час	t Время набора высоты в мин: 1000 м	t Время набора высоты в мин: 2000 м	t Время набора высоты в мин: 3000 м	u Потолок практический м	v Продолжительность полета час	w Дальность полета км	x Разбег м/сек	y Пробег м/сек
17,1	150,6	3800	600	1470	5400	33	8,6	27,5	115	78	10	22	45	3250	4	400	—	—
17,1	159,6	3800	880	1600	5100	31,8	7,3	29,6	115	80	7,3	17,9	44	3400	4,5	570	220	250
17,1	159,6	3800	880	1500	5300	33,1	7,2	28,3	115	78	12	29	—	2700	4	450	—	—
17,1	159,6	4070	656+57	1530	5400	35	7,6	27,3	115	80	11	27	—	2800	4	400	—	—
17,1	159,6	3800	656+57	1300	5700	33,2	7,16	28,3	120	78	9	20	40	3300	4	430	—	—
17,1	159,6	3900	656+57	1500	5400	33,8	7,3	28	125	78	10	25	78	3300	4	500	—	—
15,5	132	3150	690	1250	4400	33,2	7,3	25,4	120	80	—	—	—	200	4	480	700	350
17	148	3800	540+160	1100	5300	35,5	8,5	27	110	75	16	40	—	2900	4,5	520	—	—
17,1	190	4620	540+160	2000	6620	32,6	7,05	32,2	130,5	80	10,1	25,5	75	3070	4,5	620	350	—
15,2	200	4500	920+130	2200	7000	35	8	29	135	80	9	25	71	3000	4,1	560	400	300
15,8	220	5050	920+130	2450	7450	31,2	8,5	33	130	80	9,4	26	68	3250	4,4	550	420	300
15,5	190	4200	—	1900	6100	32	6,9	31,2	137	93	10	25	43	4000	4	510	350	300

f

f--Maximum speed near the ground, km/h
g--Landing speed, km/h
t--Time for climbing to altitude in min.
u--Service ceiling, m
v--Duration of flight, h
w--Flight range, km
x--Take-off run m/sec
y--rollout, m/sec

Table 10 (continued)

KEY:
1--"Grand" ("Great Baltic")
2--same
3--"Russian Chamption"
4--"Il'ya Muromets" (No. 107)
5--IM with middle wing (No.107)
6--IMC plane (No.107)
7--"Il'ya Muromets Kiev" (No.128)
8--IM-B (No.185)
9--IM-B (No.136-139)
10-IM-C("Kiev Ship" No. 143)
11-IM-C (No.151)
12-IM-C (No.150,157)
13-IM-C (No.159, 161)
14-IM-C Combat, narrow-wing
15-IM-C trainer
16-IM-C (No.167, C-21)
17-IM-C wide-wing (No.179, C-33)
18-IMD-1 (No. 183)
19-IMD-1 (No. 187)
20-IMD-1 (No. 190, D-44)
21-IMD-1
22-IMD-2 "Russobalt"
23-IMD-2
24-IMD-2 "Kiev Ship" (3)
25-IMD-2
26-IMD-3 "Renobalt"
27-IMD-3
28-IMD-3 "Renobalt strengthend"
29-IMD-2 strengthened
30-IMD-4 strengthened
31-IME-1 (EIM)
32-IME-2
33-IMF experimental
34-IMF-1
35-IMF-2
36-IMF
37-"Argus"
38-"Salm'son"
39-"Sunbeam"
40-"RBZ-6"
41-"Reno"
42-"Berdmore"

The Works of V. A. Slesarev[1]

Engineer Vasily Adranovich Slesarev is known as a designer of airplanes and has an experimenter in the area of aerodynamics. He received his higher education in Russia, completing it Germany, where he finished with the polytechnical institute. Returning to his homeland, V. A. Slesarev attended the Moscow Technical Training School, in order to receive a Russian engineer-mechanic diploma. There he worked in the aerodynamic laboratory of N. Ye. Zhukovskiy.

V. A. Slesarev began his work in aerodynamics with a study of the flight of insects: flies, mosquitoes and wasps. For this he designed and built a miniature rotating machine out of straw and wire. The insect was fastened on a definite arm and flew along a circle. The installation was surrounded by a paper cylinder, whose internal surface smoked. The ends of the insect's wing with this traced a curve line of a sinusoidal type on the paper. Exceptional precision was necessary in performing the experiments, in order to obtain good results with such small objects. The number of wing oscillations, flight speed and the power of the insects were determined. Slesarev invented special cinematographic installations for taking the pictures of the insect's flight.

At the Moscow Technical Training School he built a large rotating machine for aerodynamic investigations. Upon finishing the training school, V.A. Slesarev was invited by Professor K. P. Boklevskiy to the Petersburg

[1] "Automobile Life and Aviation", 1914, released 3, page 25, "Aero-and Automobile Life", 1914, No. 6, page 22, No. 7, page 21

Polytechnical Institute for organization of an aerodynamic laboratory there. Then he headed up a new laboratory and conducted there a number of original investigations, a result of which was the product for the large "Svyatogor" airplane.

Up to 1913, the first design works of V. A. Slesarev on airplanes included the following.

The Slesarev "Neuport" of 1914[1] was an improved modification of the "Neuports-IB" with a "Gnome" 70 hp engine. The wing span was somewhat decreased and a different propeller was installed. The speed was increased up to 110 km/h. The airplane was not accepted.

The Slesarev "Farman" of 1914 was the modification of the "Farman-XVI", in which the condola was raised upward, almost to the upper wing. They did not succeed in testing the airplane, since during take-off it nosed over and broke apart.

It is known that still in 1913, V. A. Slesarev designed and began construction of an airplane with transmission of power from the engine to two propellers.

The "Moris Farman" trainer on floats was put out by the Lebedev 239/ plant in several copies for the school of naval aviation in 1916.[2]
The two-tail "Khioni" (Andava type VKh). The airplane was installed on floats by V. N. Khioni in the summer of 1917. The floats were of the "Albatross" type. During one of the testing flight in Odessa on

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1 "Automobile Life and Aviation", 1914, release 3, page 25, "Aero-and Automobile Life", 1914, No. 6, page 22; No. 7, page 21

2 TsGVIA, f.208, op.1, d.724, l.13a.

11 August Khioni broke the airplane apart during an unsuccessful landing on the mirror surface of the quiet sea[1]. During this, the passenger sitting in the upper gondola fell out of it and drowned.

The S-XVI seaplane of I. I. Sikorskiy. In 1916 one copy of this airplane was sent on floats of the same type as the S-5a airplane. The seaplane was tested, but did not justify itself.

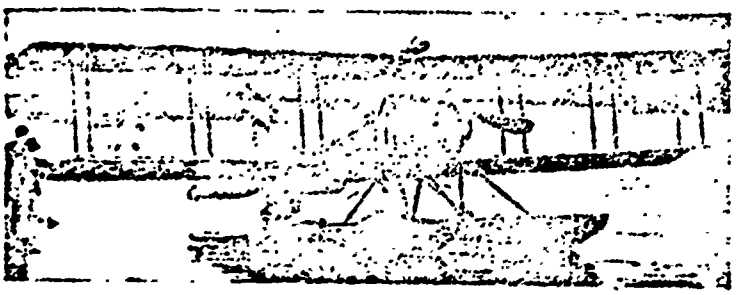

Fig. 146: "Sea-Swan" Airplane (LM-1)

The S-XX float seaplane of I. I. Sikorskiy. In 1917 one copy of it was set on floats of the same type. The work was not completed and the seaplane was not tested.

The Kostovich amphibian monoplane of 1916[2]. This was a two-place flying boat, a braced parasol with floats beneath the wings. The body of the boat was flat-bottomed with a step and transom and was wide. The cabin was open, in front of the wing. The wing was of constant profile, double-sparred with a linen covering. Its span was about 11 m. The engine had a power of 100 hp (and was apparently an in-line type). The tail empennage was carried out over the transom of the boat. On its sides

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1 TsGVIA f.493, op.10, d.117, l.421; f.208, op. 1, d.512, l.179

2 According to data of P. I. Savinov -- a witness to construction of the airplane, having contributed his earnings

were a wheeled undercarriage. The airplane was not finished due to the death of O. F. Kostovich, who passed away on 31 December 1916.

The AIS (aviation testing station of the naval department) airplane[1]. The AIS was organized at the end of 1916 and the beginning of 1917 by the naval ministry for testing seaplanes built by factories and for conducting scientific experiments in the area of naval aviation, and for the intelligent acceptance of materiel and development of technical conditions for its procurement.

At the AIS a design bureau located at the polytechnical institute, and a test seaplane base at Krestovskoye Island in Petrograd were organized at the end of 1916. The design bureau of AIS was organized for planning experimental naval airplanes on a level with the factories.

At the head of AIS were marine engineers P. A. Shishkov (chief) and Sushenkov (heading up the calculation and design part).

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1 TsGVMA, f.61, d.41, ll. 61,64,69, 69. d.43; ll.59,69
TsGAKA, f.28, op.1, d.19, l.140

CHAPTER IV

THE STATE OF AVIATION ENGINEERING AND INDUSTRY IN RUSSIA UP TO OCTOBER 1917 244/

Development of Design Elements in Airplanes of Russian Build

The development of airplane design is examined here beginning with 1909-1910, i.e. on the first years of the establishment of Russian aviation. The airplanes which were created earlier are not discussed, since they, with the exception of the airplane of A. F. Mozhayskiy, were sufficiently fully examined in Chapter I, and were not finalized designs.

In accordance with the level of development and science and engineering in the period being examined almost all designs of Russian airplanes could be included in the number of braced wooden and mixed ones. The wings and fuselages of airplanes created by Russian designers were basically these. The exception was only the wing of the "Steglau No. 2" airplane, where a working plywood skin was used. Among fuselages the exception consisted of designs of the monocoque type of which ten can be counted, namely: the "Dolphin", S-9, "Anamon", "Anadis", Torpedo", "Swan-Monocoque", Grand Swan", "AIS", "Kasyanenko No. 5" and the Modrakh". There were also exceptions in the form of frame constructions out of steel tubing with soldering or welding, which were used in the airplanes of the designs of Dokuchayev , Rebikov, Orlov, and Subbotin. Besides this, their fuselages with a working plywood skin along the entire length: the "Stegan No. 2" and "Swan" airplanes, or only in the nose part with a linen tail covering.

The longerons of a braced fuselage were usually made of pine, besides the front curved sections, which were made out of ash, joined together with

miter joints and with the joints wrapped with tape using glue. All braces were also made out of pine, with the exception of those beneath the engines, which were ash. The multitudinous joining parts were made approximately according to a common type (fig. 148,f) which had been arrived at already in 1912 and with slight improvements existing even now. Before this improvised primitive parts had been used.

The simplest type of these units were wooden or plywood linen-glued plates, which were used in the Kiev designs ("Sikorskiy cups"), (fig. 148,a). The end of the brace was inserted in the square hole, and the plate itself was set on the longeron with glue and on bolts, by which the bracing eyes were fastened. The "Farman" cups (see fig. 148,c) served the same purpose. In 1910-1911, units made out of a single plate, bending around the round section of the fuselage longerons (see fig. 148,b) were also used in the Kiev design. Simple inserts were also used (see fig. 148, d). Units which were similar to those described were also used in the wooden frames of airplanes without fuselages. Sometimes wiring bracing was fastened directly beneath the heads of bolts. In the fuselages of the "Muromets" the braces were doubled, there were two holes in the unit eyes, and welding was usually used (see fig. 148, g).

The braces were made out of single strand wire and in certain cases they were cable. In each brace was a tender with a brass sleeve. Since the tenders were relatively expensive, during the first years, various homemade devices were frequently used for stretching bracing wires, for instance, spoke stretchers (see fig. 148, e) and brackets for them were a prototype for future threaded brace wires. The same formed braces of lenticular

section were not mastered in Russia and came to us in 1917 in the English "Sopwith Scout" airplanes. In Russia already in 1911 the Kiev designers installed two (and sometimes three) wire braces onebehind the other to decrease frontal drag. From 1912 they made fairings for pairs of such wires (or cables) in the form of wooden slats, inserted between them, with a common covering of linen. This construction was then widely used in the RBVZ airplanes and others. It did not, however, go into series practice in other enterprises.

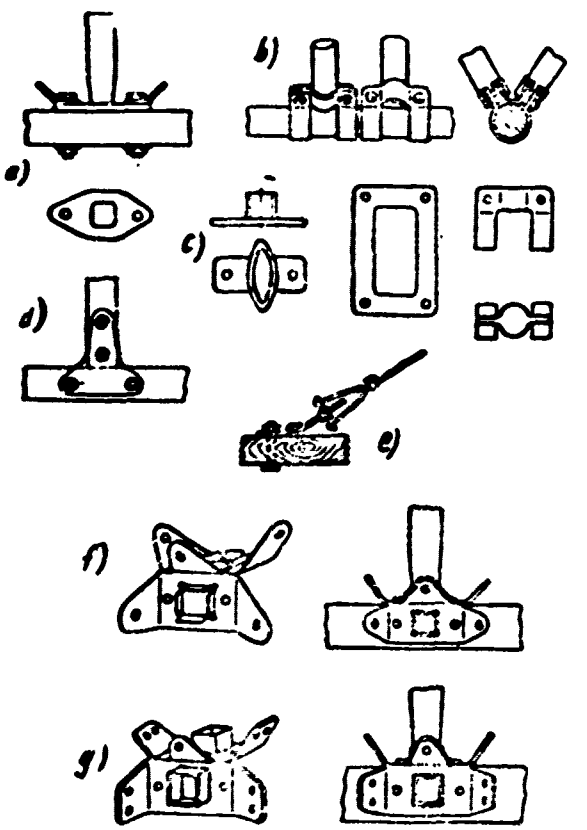

Fig. 148: Units of Braced Fuselages in Russian Airplanes:
a--"Sikorskiy cups" b--early type of unit c--"Farman cups"
d--plate joints 3--early form of brace wire f--typical joints
g--joints of the "Muromets"

Transmittal of control in early Russian airplanes up to 1912-1913, was usually made with wire, and later with cable. The ends of the cable were finished with braiding into an eye. The art of braiding small diameter cables was mastered very rapidly by us. Other forms of finishing which had long been in use abroad -- clamps, twisting and soldering -- were almost never encountered.

In the area of wing design the Russian engineers were original. Wings and empennages with a working (in particular, plywood) covering were built for the first time and the wing for the large airplanes of 1913-1915 were built for the first time in Russia. Typical contours of wings in plan and their profiles are given in figures 149 and 150.

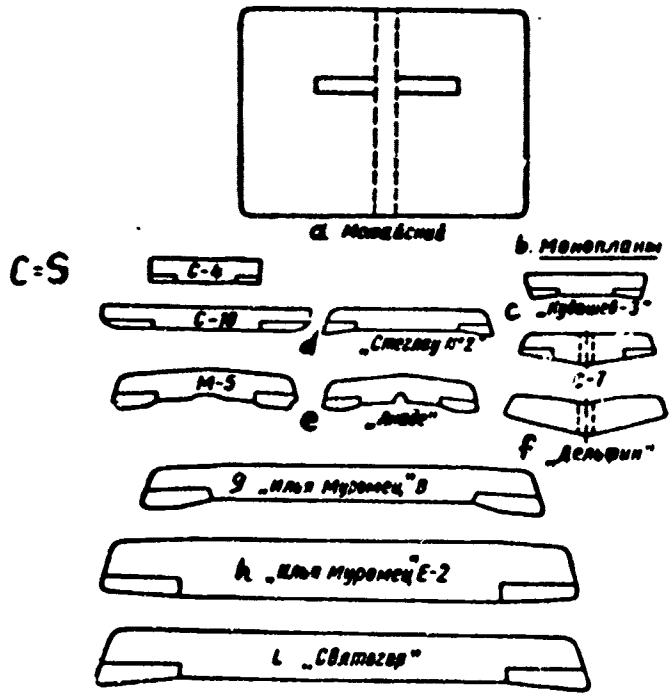

Fig. 149: Wing Contours of Russian Airplanes
(Key on page 83)

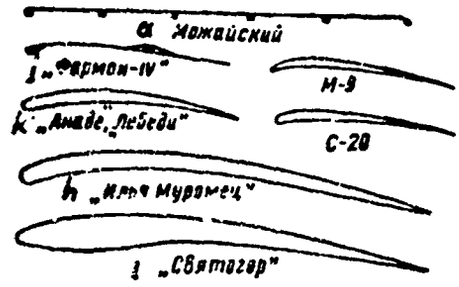

Fig. 150: Profiles of Russian Airplane Wings

Key: (Figs. 149 and 150)
a--Mozhayskiy
b--Monoplanes
c--Kudashev-3
d--Stegan No. 2
e--Anade
f--Dolphin
g--Il'ya Muromets C
h--Il'ya Muromets F-2
i--Svyatogor
j--Farman-IV
k--"Anade", "Swans"

The wings were almost always double-spar. The design of the spars changing from a simple pine beam (or even a bamboo stick), and through milling, I-beam and hollow section moved toward the box section with plywood walls and plates out of pine or a stronger wood (rarely) which was commonly accepted later (fig. 151,a). The plywood was fastened to the shelves with glue, screws and nails. They began to make holes for air only in 1916 (on the "Muromets"). Design of ribs was generally uniform -- a plywood wall with lightening holes and pine plates with a slot into which the edges of the plywood went with glue and small nails or screws into the plywood edge (see fig. 151,b).

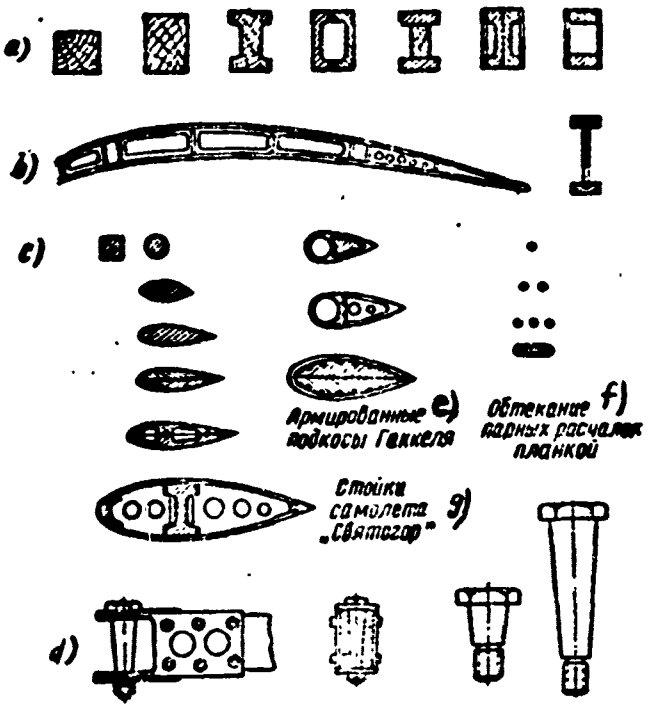

Fig. 151: Elements of Wing Design in Russian Airplanes: a--section of spars b--typical rib c--section of strut and braces d--joint with conic bolts e-- reinforced Gakkel' strut f--streamlining of paired wires with a lath g--struts of the "Svyatogor" airplane

Ailerons were already used in Russian designs since 1910 and moved fully into practice in 1912, while many French airplanes ("Moraines" and others) still in 1916 retained warping (gauching [Fr. gauchir-to warp]) of the wings. In a number of cases the Russian designers reworked the wings of French airplanes, replacing the gauches with ailerons, especially in the "Neuport-IV" airplanes.

The designs of wing cell struts and tail frames was established very early (see fig. 151,c). The first form was wooden beams of rectangular

section, and almost immediately behind it was beams of round section, lenticular, streamlined, bamboo stick, and then pipes without streamlining and with streamlining (Ya. M. Gakkel', 1909). To avoid bending of the struts of streamlined sections, they begin to glue them out of two boards, and in 1912, they began to make them hollow. The connection of the two halves was done on plywood strips 5 mm wide, inserted with glue into slots which were milled in the strut halves. The reinforced gakkel' struts appear. The types of wing cell struts came full circle with the mammoth struts of the "Svyatogor" airplane of original section, which were very light and rational. The ends of the strut were finished in welded cups, while up to 1911 they were sometimes simply inserted in sockets in the joints.

Steel tubes for wing cell struts and frame constructions and also for the wing spars of the "Farman" and "Voisin" airplanes were scarce in Russia and were almost unused in our designs. However, soldering and welding them in butt joints were accomplished in Russia generally later than in other countries. Examples where the airplanes of Dokuchayev, Rebikov and Steglau.

Ball bearings as imported products were almost not used in Russian airplanes.

In the area of airplane undercarriage design, Russia was in a visible place. A. F. Mozhayskiy used wheels in the models and in his airplane, and in 1910, A.F. Kudashev constructed an original arched undercarriage--the prototype for standard undercarriages with a through axle, guides for if and bungee cord shock absorption. In 1913 an undercarriage was built for giant airplanes. The undercarriage of V. M. Ol'khovskiy essentially

improved the original models of French undercarriages of those airplanes.

All joints in Russian airplanes are made out of sheet steel, usually with welding and were fastened to the wooden frame with bolts. Sometimes conic bolts were used, for example in the "Muromets" (see fig. 151,d).

Duralumin was absolutely absent in Russian designs. They knew it from the literature and it was an imported and war trophy airplanes, but in Russia it (like aluminum) was not produced, and it had no allies. There were also no forged and stamped parts, and no plastics. Engine cowlings, small fairings and sections of skin in points which were dangerous from the point of view of fire were made of sheet aluminum.

Since 1912, "emalite" -- a nitrocellulose lacquer, first appearing in France, became the commonly used and best covering in Russian airplanes. It assured remarkable tightness of the linen. However, emalite as airplane dope, as it came to be called here, was too expensive and therefore cheaper forms of covering continued to be used for many years hence.

Rubber impregnated linen was used in a number of early airplanes and then the covering was superfluous. For airframes, however, a skin and covering which was much lighter and cheaper was required. And here the method was discovered of covering the linen with starch (sizing), i.e. potato flour diluted in hot water. This covering provided satisfactory tightness of the linen and was cheaper. It dissolved and washed off from moisture and rain, but it could be very rapidly renewed. Therefore, for trainer airplanes of older types this starch covering continued to exist up to 1916.

In Kiev, they began to use in place of starch a "hot mixture" -- an invention of mechanic V. S. Panasyuk: a glue solution out of furniture glue and drying oil, thinned with denatured alcohol. The linen covering was soaked

with this emulsion and when it hardened and dried out the linen tightened rather well. Then it was covered with yacht (resin) lacquer. After this the covering was sometimes treated with pumice and again covered with lacquer. A very fine and stable covering was obtained. In good weather the tightness of the linen was ideal, but in moisture, and also during the night it sagged. There was another composition, the so-called "Sikorskiy patent": the hot mixture of drying oil with alcohol and yacht lacquer. With it the tightness was good, but the flexibility created disturbed warping.

Another composition for non-combustal covering of linen can be named out of the early coverings: resin lacquer (from moisture), gelatin and salt. Another composition was starch with calcium bichromate (orange crystals). Another composition under the name "navazhka" was used, but now no one remembers of what it was made.

In practice in the Russian plants in 1915, one coat of the so-called Koch's airplane dope (nitrocellulose) was used and a coat of No. 17 lacquer (oil) was used along it. This Koch's airplane dope was named for Koch -- owner of the Dorogomilovskiy plant in Moscow, evacuated from Riga in 1915.

In 1918 they begin to manufacture there A-N (nitrocellulose) and Al-Ts (celluloid) airplane dopes for the first coat, and from 1924 they also manufactured second coat airplane dope -- the light AP-k (brush) of protective coloring and pale blue (for the lower surface of airplanes). Skis for airplanes were absolutely original Russian products. Yu. Kremp built the first skis in the world for his airplane in 1909. The first official experiments with skis were conducted in the winter of 1910-1911 at a Sebastopol school

by Captain (junior grade) Kedrin and Lieutenant Piotrovskiy. Skis according to their plan were manufactured by the Akstman plant. The skis were fastened to the undercarriage wheels. The tests were successful[1]. Designer N. R. Lobanov in 1912 proposed that the upper side of the ski runners and a large part of the cabane be enclosed in a fairing. This was gradually accepted for all skis. He also proposed a tail stabilizer for skis, eliminating lowering of their noses and replacing the guy wires. The tests were successful[2], but this ideal is not accepted, since there was no confidence in the failure-free operation of the stabilizer and the guy wires always remained. The fairings of the upper sides of the skis were initially made of linen on a frame, and then out of thin plywood with glued linen and their frame became load-bearing for strengthening the undersides of the skis. The cabane, originally wooden, began to be made welded with steel tubing. The basic parameter, defining the dimensions of the skis -- the load per 1 m^2 of their dimensional area -- changed in the direction of a gradual increase. In the first skis of the times, they used 300-350 kg/m^2 and the "Muromets" the load on the skis reached 900 kg/m^2. The relative length of the skis, i.e. relationship of their length to their width, was from 15 in the very earliest skis up to 3 in the very largest ones.

In Russian airplane building a number of examples can be observed of

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[1] "Sebastopol Aviation Illustrated Journal", 1911, No. 11, 30 January "To Sport !", 1913, No. 3 page 7

[2] "Aero-and Automobile Life", 1913, No. 6, pp. 11-14

the fact that the designers consistently developed a definite line of gradual improvement of their first airplane, as a rule, acheiving positive results. This is the way the Russian designers Gakkel', Sikorskiy, Grigorovich and Villish progressed.

In the works of Ya. M. Gakkel' (fig. 152) an exceptionally well expressed in the development of his airplanes from type to type is visible. The matter progressed toward development of superb reconnaissance planes -- the fuselage biplane and a strut monoplane. I. I. Sikorskiy over the three years of his activity travelled a path from a primitive frame biplane with a power of 15 hp up to the giant airplane "Russian Champion" and "Il'ya Muromets" (fig. 153),a path of sequential development of the layout of a multistrut biplane, which for those times was the only one possible for large airplanes.

The development of the flying boats of D. P. Grigorovich (fig. 154) went along the line of developing a three-strut biplane on the body of a boat and was completed with creation of the large MK-1 seaplane. A. Yu. Villish developed his three flying boats well, but was hampered by the erroneous idea of [end of text].

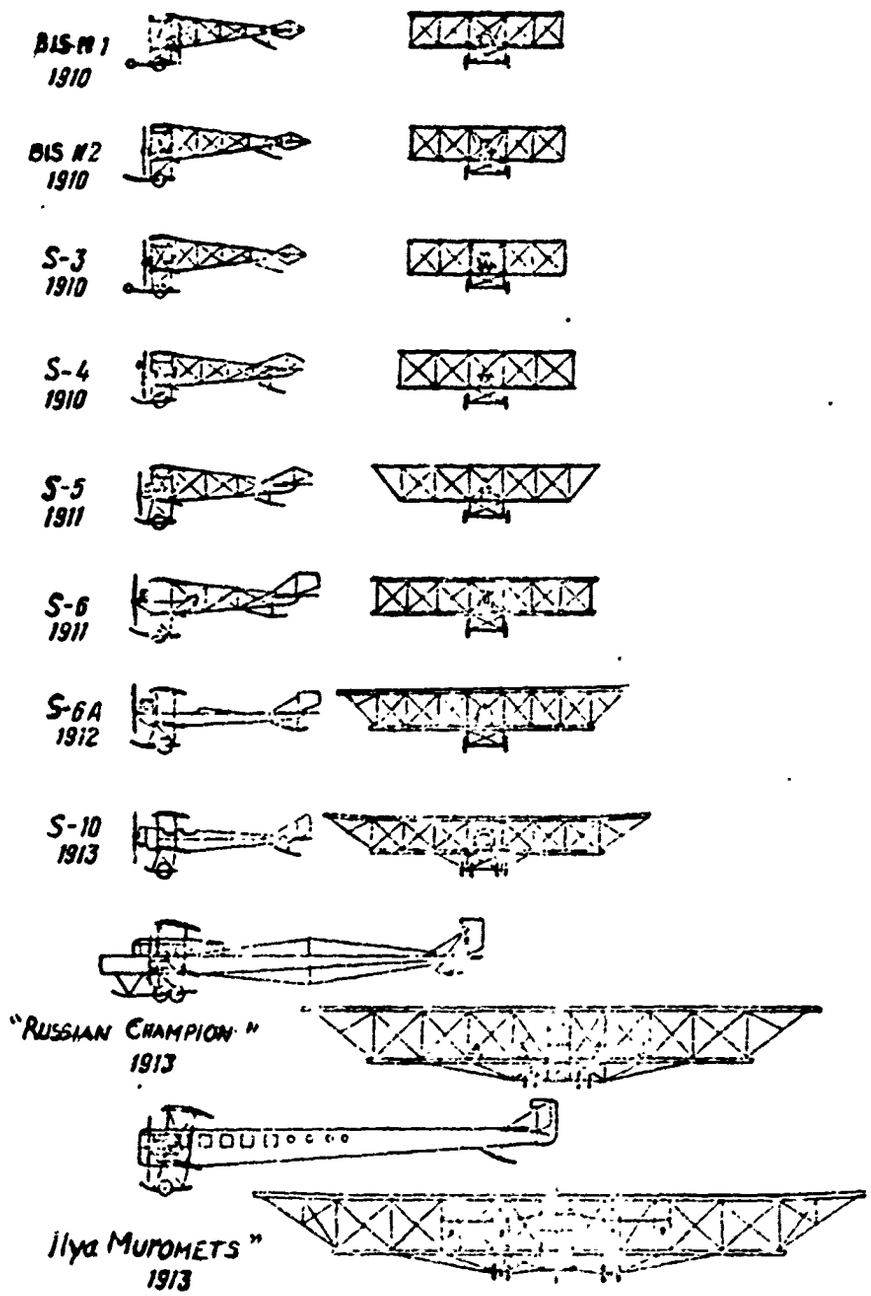

Fig. 153: Development of the Planes of I. I. Sikorskiy